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SCIENCE AND TECHNOLOGY IN JAPAN -- A BRIEF ANALYTIC SURVEY

Ed McGaffigan, et al

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An exploration of the strengths and weaknesses of Japanese science and technology, including an estimate of the importance of foreign technology to Japanese technological advancement and an examination of the power of Japanese business management and government policy over scientific and technological development. Possible areas for U.S.-Japanese collaboration are identified. Today government policy in Japan is to concentrate on and to invest more R&D funds in "knowledge intensive" areas, such as computers, fine chemicals, nuclear energy, semiconductors, and other industries where significant levels of R&D expenditures are required to compete on world markets. Projects chosen aim at satisfying long-term national and industrial needs. Japanese transportation problems stimulated research on road traffic control and magnetically levitated trains. Pollution promoted research on flue gas desulfurization and electric cars. The greatest opportunity for government to government cooperation lies in large-scale projects of national interest, such as magnetohydrodynamic power generation, plasma fusion, road traffic control, cryogenic power transmission, magnetically levitated transportation, and solar energy. (BG)

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PREFACE

In recent years, Japanese science and technology have made remarkable strides, approaching in that respect parity with the Western developed nations. At a time when even the United States can no longer expect to lead across the entire vast spectrum of scientific and technological work, it is becoming increasingly important to keep abreast of the relevant effort in other advanced countries, both allies and adversaries. Without such information neither effective competition nor fruitful cooperation is possible.

The present report attempts to give an overview of the present state of Japanese science and technology R&D and to assess briefly some of the major fields of that effort. This study was conducted under the auspices of the Defense Advanced Research Projects Agency (ARPA) and is intended as a contribution to that agency's continuing concern with science and technology R&D abroad. It also relates to ongoing Rand research on various technological and economic aspects of R&D in the United States and in foreign countries.

SUMMARY

This study seeks to identify the strengths and weaknesses of Japanese science and technology; to estimate the importance of foreign technology to Japanese technological advancement; to examine the power of Japanese business management and government policy over the development of science and technology; and to identify possible areas for U.S.-Japanese collaboration.

Japan's science and technology are developing rapidly, as can be seen from Japan's acquisition of U.S. patents, international cross-licensing agreements, participation in international joint research efforts, and the growing list of Japanese scientific and technological achievements.

Japan has mounted an intensive campaign to promote domestic technology. Most of the effort has been concentrated in the major industrial corporations and in the research institutions associated with government agencies and ministries, which work closely with the large industrial laboratories. Technology with a strong commercial potential has been the focus. (Basic research, largely the province of the universities, has been poorly funded; and research related to military, space, and other national interest applications has been unimportant.) The industrial effort has been selectively applied to a small number of industries; electrical machinery and electronics, autos, chemicals, iron and steel, and ships account for most of Japan's industrial R&D expenditures.

Much of the basic technology upon which Japanese efforts build has been imported from abroad by licensing. Prior to 1968, a time when the Ministry of International Trade and Industry (MITI) tightly controlled foreign investment in all sectors, the Japanese systematically went about acquiring the technology upon which to develop their economy. The United States was the source of almost 60% of that technology. Technical assistance agreements were concluded in fields from petrochemicals to computers, typically calling for royalties of less than 5% of sales--a bargain for Japanese industry.

Since 1968, with Japan's accelerating movement toward broad technological parity with the West, the quantity of imported technology has continued to grow while its character has been changing. There has been a movement away from technical assistance agreements toward pure patent licensing. Cross-licensing has also increased, and Japanese companies have undertaken joint research with U.S. companies. There have been a few well-publicized exports of technology in such areas as urea fertilizer and automotive engines, with the Japanese selling improved technology back to its source.

Japanese research efforts have largely paralleled those of the United States, but Japanese industry still has difficulty competing head-on with the giant American companies. For example, IBM's $730 million annual expenditure on R&D allows it to conduct research in very-high-risk basic research areas, such as cryogenic computers. No Japanese company can hope to emulate such an effort. Bell and Corning Glass have been more successful in developing optical fibers than have NEC and Nippon Sheet Glass with their comparatively limited means. High-temperature superconductors and high-energy pulsed lasers will be developed in the United States rather than in Japan.

Japanese companies instead specialize in developing and improving existing technology. For example, the Japanese are not leaders in basic research on artificial intelligence or high-temperature superconducting materials, but they have developed some very interesting industrial robots and the commercial production of V_3Ga wire. They did not originate the electron microscope, but they have become leaders in its development. The same is true for the Tokomak concept for fusion reactors, welding technology for shipbuilding, and oxygen converters for iron and steel manufacturing.

The Japanese have had to be selective in choosing where to concentrate their R&D efforts, and high-risk pioneering research has been given low priority for the most part. This can cause problems for the Japanese, for there is always the danger of being leapfrogged by developments elsewhere. Possible examples are fermentation technology and ship propulsion systems, in which Japanese industry has reached high levels in the conventional technology.

Advanced technology may be increasingly expensive to license. With foreign investment largely decontrolled, foreign firms will be more insistent on joint ventures, and market restrictions on the licensee may become increasingly onerous. One detects a reluctance among some U.S. companies to license technology to Japan now that the Japanese are approaching technological parity. (But any reluctance has yet to be reflected in the licensing statistics. This question is worthy of further more systematic study.)

Today government policy in Japan is to concentrate on and invest more R&D funds in "knowledge intensive" areas, such as computers, fine chemicals, nuclear energy, semiconductors, and other industries where significant levels of R&D expenditure are required to compete on world markets.

Japan's technological capabilities will be challenged by the goal of restructuring industry to decrease emphasis on the heavy industries, which consume large amounts of raw materials and where technology is relatively stable, and increase emphasis on "knowledge intensive" industries, which have a high value added and whose technology is rapidly changing. Her greatest successes in the past have been in areas of stable technology. Pioneering breakthroughs have been rare and indeed have not been sought. The new basic research program will require greater levels of R&D funds. There is especially room for improvement in funding university research, but industry could also bring its R&D expenditure as a percentage of sales more in line with U.S. figures.

Because present economic difficulties make substantial real growth in R&D expenditures unlikely, the shift toward "knowledge intensive" industries is likely to be gradual for the next several years. The Japanese will still have to be selective, but they have long demonstrated their ability in product-oriented R&D of commercial importance; and such developments as Toyo Rayon's carbon fiber, Professor Masumoto's amorphous steel alloy, and Furukawa Electric's, superconducting wire indicate they will be successful in product development in "knowledge intensive" areas, even if most fundamental innovations continue to come from abroad.

The government is responsible for the long-term, large-scale research efforts. Deciding where to concentrate government R&D efforts involves accommodating the interests of the different government agencies and often of industry. The projects chosen aim at satisfying long-term national and industrial needs. Japanese transportation problems stimulated research on road traffic control and magnetically levitated trains. Pollution promoted research on flue gas desulfurization and electric cars. The lure of oceanic resources has stimulated research on desalination and remotely controlled, deep-sea oil drilling. New sources of energy and the efficient uses of present energy resources are also emphasized.

The greatest opportunity for government to government cooperation lies in large-scale projects of national interest, such as magnetohydrodynamic (MHD) power generation, plasma fusion, road traffic control, cryogenic power transmission, magnetically levitated transportation, and solar energy. Both the United States and Japan have a keen interest in those fields and could mount joint efforts to their mutual benefit.

CONTENTS

TABLES

GLOSSARY OF ABBREVIATIONS

AIST	-	Agency for Industrial Science and Technology
CMOS	-	Complementary metal oxide semiconductor
ECL	-	Electrical Communications Laboratory
ETL	-	Electrotechnical Laboratory
IC	-	Integrated circuit
JAERI	-	Japan Atomic Energy Research Institute
JNR	-	Japan National Railway
KDD	-	International Radio and Cable Corp.
LED	-	Light emitting diode
LSI	-	Large scale integration
MITI	-	Ministry of International Trade and Industry
MOS	-	Metal oxide semiconductor
NASDA	-	National Space Development Agency
NEC	-	Nippon Electric
NHK	-	Japan Broadcasting Corp.
NMOS	-	n channel metal oxide semiconductor
NTT	-	Nippon Telephone and Telegraph Corp.
OS	-	Operating system
PMOS	-	p channel metal oxide semiconductor
ROM	-	Read only memory
STA	-	Science and Technology Agency
TI	-	Texas Instruments

I. INTRODUCTION

The goal of this study is the assessment of the present status of Japanese science and technology. We have five main objectives.

First, we will attempt to identify *strengths and weaknesses* of Japanese science and technology. In which fields do the Japanese have strong research and development capabilities? In which fields do they concentrate their efforts? Where have the greatest accomplishments been achieved? Where have there been failures?

Second, we will attempt to find *reasons for these strengths and weaknesses*, placing the present situation in historical context. Was a given individual important? Are there national characteristics or circumstances that call for priorities different from those elsewhere?

Third, we will examine the role that the *importation of foreign technology* has played in the development of Japanese science and technology in the post-World War II period. How has the character of that importation been changing as the Japanese reach world technological levels? How have the Japanese gone about acquiring this foreign technology? How may the attitudes of the suppliers of the technology be changing? How are Japanese attitudes to the importation of technology changing?

Fourth, we will examine Japanese *business management and government policy*, as well as their interaction, to determine how these facts affect research and development in science and technology. Does government have a longer term outlook? Is the attitude toward domestic R&D and to the importation of foreign technology changing? Are the approaches to managing R&D changing, especially in "high technology" or "knowledge intensive" areas?

Finally, our long-term objective is to identify *possible areas for fruitful U.S.-Japanese collaboration*, a subject of special concern to U.S. and Japanese government agencies. Therefore, our approach has been comparative. We use the United States as a yardstick to measure Japanese programs. Comparisons are also made with West European

nations and the Soviet Union when appropriate. We will touch upon the question of collaboration in our Conclusions.

This report is but a first attempt to clarify the above key questions. We have worked under limitations of time and of access to materials. We have made extensive use of a wide range of sources of information that were available. This included a variety of statistical data from U.S., Japanese and OECD public agencies, previous official and private surveys of various aspects of Japanese science and technology, recent review articles of specific areas, reports of important recent developments, assessments by specialists, and interviews with scientists and engineers who have a direct personal knowledge of Japanese R&D efforts, often through extended stays in Japan or participation in technical assistance programs. We were able to talk to several Japanese scientists, working in or visiting the California area. We have attempted to check our sources against one another.

We focus for the most part on industrial science and technology. This is the area of greatest Japanese strength and emphasis, and perhaps the area of greatest interest to U.S. government agencies. In addition statistical data were much more extensive in covering industrial research efforts, and judging the quality of the research could be somewhat more quantitative. University research as it relates to areas of industrial interest will also be discussed.[1]

In dealing with this very big and complex subject we have encountered many problems. Most of these are of a methodological nature, and are topics of current research in the field of diffusion of technology. International comparisons are difficult to make. Definitions of researcher and of research and development vary from country to country, as do attitudes to importing technology. Criteria for assessing relative strengths and weaknesses remain qualitative. We have found it difficult to measure the extent of improvement of imported technologies in any quantitative fashion, especially when dealing with the cumulative effect of the small improvements for which the Japanese are renowned.

Measuring the extent of dependence on foreign technology is also a difficult task. How much technology is transferred in the open literature? Does the absence of technical assistance agreements make a company independent? These are questions we cannot really address here. We will point out problems with the methodological tools we use in the text. Further study to develop methodological tools for this sort of international technological comparison is clearly warranted.

We will organize the report as follows. In Section II we present an overview of science and technology in Japan. We discuss the structure of research and development -- government policy, business management, and the role of foreign technology. In Section III we present summaries of the present status of selected areas of industrial science and technology. This review is not meant to be exhaustive, but to help reveal patterns and trends in overall Japanese capabilities. Supporting statistical evidence of possible interest to some readers will be placed in the appendix.

Footnote

The main area we are neglecting is basic research in the universities on areas of immediate interest to industry. This includes medicine, astronomy, geology and seismology, most of mathematics, most of biology, and much basic physics. Work in these areas is almost exclusively done in the universities. Our neglect does not mean there are not significant achievements. In such diverse fields as geophysics, meteorology, and the study of gastro-intestinal cancer, the Japanese are among the world leaders. In all three of these cases the need to solve problems important to Japan have spurred efforts. On the other hand, in such fields as experimental high energy physics and astronomy, which require significant expenditures and involve only intellectual returns, the Japanese work is rather modest.

II. OVERVIEW OF SCIENCE AND TECHNOLOGY IN JAPAN

A. RESEARCH AND DEVELOPMENT IN JAPAN -- OVERALL BUDGET AND MANPOWER

In fiscal 1972 (April 1, 1972 - March 31, 1973) Japan spent 1586.7 billion yen (about $5.3 billion) on research and development in science and technology.[1] This expenditure has been growing very rapidly from a very low base, outpacing the rapid increase in Japan's GNP.[2] (See Table 1)

In 1972 Japan devoted 1.66% of GNP to research and development in science and technology. This percentage is still well below those of the U.S. (2.6% in 1971) and the U.S.S.R. (3.0% in 1971), and slightly below European percentages (West Germany, 2.01%, France, 1.75%, U.K., 2.11%, all in 1971).[3] The Japanese percentage has been rising slowly over time, with the biggest jump occurring in the late 1960's.

It will be interesting to see if total R&D expenditures keep up with the rapid rate of inflation in fiscal 1973 and fiscal 1974.

Japanese statistical data identifies three sectors of R&D performance:[4] private industry, research institutions, and universities. Private industry includes public corporations such as Japan Broadcasting Corporation (NHK), Japan National Railway (JNR), and Nippon Telephone and Telegraph (NTT). Research institutions include all government research institutes, chartered corporations established solely for research purposes such as the Japan Atomic Energy Research Institute (JAERI) and the Physical and Chemical Research Institute, non-profit organizations, and private foundations. Universities include all national, public, and private universities and colleges, and their associated research laboratories.[5]

The industrial sector is preponderant (Table 2). Aside from a brief period in the mid-1960's the share of the industrial labs in R&D expenditures has been about 66%. The universities have averaged about 19% and the research institutions about 15%. In this respect Japan is not unlike the U.S., where $18.4 billion out of the $27.3 billion spent in 1971 on R&D (67%) were spent in the industrial sector.

Table 1

EXPENDITURES ON R&D COMPARED TO GNP, FY 1961-1972

Fiscal Year	Expenditures on R&D Billion Yen (A)	GNP Billion Yen (B)	A/B (Percentages)
1961	245.2	19,853	1.24
1962	281.2	21,660	1.30
1963	321.1	25,592	1.25
1964	381.8	29,662	1.29
1965	425.8	32,813	1.30
1966	488.7	38,450	1.27
1967	606.3	45,322	1.34
1968	767.8	53,368	1.44
1969	933.2	62,997	1.48
1970	1195.3	73,248	1.63
1971	1345.9	81,093	1.66
1972	1586.7	95,564	1.66

SOURCES: Bureau of Statistics, Office of the Prime Minister. *Report on the Survey of Research and Development in Japan* (for 1973). Tokyo, 1974, p. 48 (Hereafter cited as *R&D in Japan*).

Budget Bureau, Ministry of Finance. *The Budget in Brief - Japan 1974*. Tokyc, 1974, p. 6.

Bureau of Statistics, Office of the Prime Minister, *Japan Statistical Yearbook, 1972*. Tokyo, 1973, p. 487.

NOTE: 1. All figures are in current yen.

2. Japan's fiscal year runs from April 1 to March 31. FY 1972 goes from April 1, 1972, to March 31, 1973.

Table 2

EXPENDITURES ON R&D IN SCIENCE AND TECHNOLOGY
(% share of each sector - Japan)

Year	Universities	Research Institutions	Industry
1953	29	17	54
1955	29	19	55
1958	20	19	61
1961	17	16	67
1962	19	17	64
1963	20	16	65
1964	20	16	64
1965	25	16	59
1966	24	16	60
1967	23	15	63
1968	20	14	66
1969	19	14	67
1970	18	13	69
1971	19	15	66
1972	18	16	66

SOURCE: *R&D in Japan, 1973*, Summary Table 2-2, p. 48-49. Organization for Economic Co-operation and Development, *Reviews of National Science Policy, Japan*. Paris, 1967, p. 184.

NOTE: Science and technology includes natural science, engineering, agricultural science, and medicine.

In 1972 private sources provided 73% of funds for R&D in science and technology in Japan, with the remaining 27% coming from the government. This is the smallest percentage of any of the large developed nations. (Table 3 presents a comparison with other nations.) Germany most closely resembles Japan with 60% of expenditures coming from private sources, while the government contribution is greater than 50% for the U.S., U.K., and France. One basic difference responsible for Japan's low percentage is the low funding of defense-related R&D in Japan reflecting postwar Japan's de-emphasis of military expenditures. Military objectives account for much of the government support of industrial R&D in the U.S. and elsewhere.

In 1972 government support for the industrial sector in Japan was only 2.6% of all expenditures for research in that sector.[6] The government supplied 86% of the funds for research institutions, 99% of the funds for national and public universities, and 9% of funds for private universities. We will see that much of the 27 billion yen going to industry is used for very specific purposes. This $90 million grant to industry is of course dwarfed by the grants in other countries: In 1971, U.S. government support of industrial R&D stood at $7.8 billion, 42% of all industrial R&D expenditures. This should not be taken as an indication of the relative influence of government on industrial R&D policy, however.

The different sectors put a different emphasis on various types of research and development.[7] The industrial sector clearly concentrates on applied and developmental research. Only 8% of 1972 expenditures was for basic research, 22% was for applied research, and 70% for developmental research.[8] The research institutions place their greatest emphasis on applied research. The universities emphasize basic research in science. Because of the heavy stress on basic and applied research in the universities and research institutions, Japan actually devotes a relatively high percentage of its overall science budget to this sort of research. In 1971, 50.2% went to development, 25.8% to applied research and 23.9% to basic research.[9] For the U.S. in 1971, basic research received

Table 3

EXPENDITURES ON R&D: SOURCES OF FUNDS, FY 1969-72
(In percent)

Country	Year	Public	Private
Japan	1969	26.3	73.7
	1970	25.2	73.8
	1971	27.4	72.6
	1972	27.2	72.8
U.S.	1970	56.2	43.8
U.K.	1969	50.6	49.4
France	1969	62.3	37.7
West Germany	1969	39.1	60.9

SOURCES: For United States: National Science Board, National Science Foundation, *Science Indicators, 1972*, Washington, D.C., 1973, p. 109. For other countries: Science and Technology Agency, Prime Minister's Office, *Summary, Fiscal Year 1972: White Paper on Science and Technology*, Tokyo, 1973, p. 48; *R&D in Japan, 1973*, p. 50.

Table 4

MANPOWER DEVOTED TO R&D IN DEVELOPED NATIONS

Country	Year	Number of Researchers	Researchers per 1000 Population
Japan	1970	172,002	1.7
	1971	194,347	1.9
	1972	198,084	1.9
	1973	226,604	2.1
U.S.	1972	535,000	2.6
U.K.	1972	43,588	0.8
France	1972	54,692	1.1
West Germany	1972	72,004	1.2
U.S.S.R.	1970	672,080	2.8

SOURCES: *R&D in Japan, 1973*, p. 25; *Technocrat*, January 1974, p. 93.

14.3% of expenditures, applied research 22.3%, and development 63.4%.[10] (However, one must be wary of definitional problems between countries.)

One characteristic of Japanese research and development is the large amount of manpower devoted to the effort. In 1973 there were 227,000 regular research workers in Japan.[11] This was 2.1 researchers/ 1,000 of population. This approaches the U.S. figure of 2.6 researchers/1000 of population in 1970, and exceeds significantly the figures for West Germany, France, and the U.K. (Table 4).[12]

Of the 227,000 regular researchers in 1973, 125,000 were employed in companies, 27,000 in research institutions and 75,000 in the universities. The number of researchers has been increasing steadily over time (Table 5) with growth especially rapid in the university and industrial sectors. In fact, in 1972 the number of Japanese university researchers passed the number of U.S. university researchers. However, university researchers are very poorly supported in Japan. Expenditure per researcher in the university sector was only 3.8 million yen in 1972, as opposed to 9.5 million yen in the research institution sector, and 8.4 million yen in the industrial sector. Low university funding has been the historical pattern in Japan (Table 6). Note that the slow increase in the number of researchers in the research institution sector has allowed that sector to become the best funded per researcher.

Another indication of the relative prosperity of the different sectors of performance of R&D is the division of expenditures among wages and salaries, materials, fixed assets, and other expenditures. A higher percentage of the universities' already meager funding goes to salaries and wages than in the other sectors (Table 7) leaving even less for equipment and other expenses required to do research. This underutilization of university researchers is a major problem for Japanese science policy.

Table 5

RESEARCHERS IN R&D, BY SECTOR;
JAPAN-U.S. COMPARISON

Japan	Industry	University	Research Institutions	Total
1961	46,110	28,337	16,520	90,967
1965	65,357	43,625	19,946	128,928
1968	82,516	52,373	22,168	157,057
1969	94,060	55,240	22,702	172,002
1970	111,244	59,747	23,356	194,347
1971	112,763	60,503	24,818	198,084
1972	124,795	75,159	26,650	226,604

U.S.	Industry	University	Federal Government	Other	Total
1961	312,000	42,400	50,600	20,200	425,200
1965	348,400	53,400	64,200	30,500	496,200
1968	381,900	66,000	68,300	34,400	550,600
1969	385,800	68,300	70,300	35,000	559,400
1970	377,400	68,500	69,800	34,000	549,700
1971	363,400	68,400	68,500	32,500	532,800
1972(Est.)	356,000	67,600	68,000	33,800	525,400

SOURCES: *Science Indicators, 1972*, p. 110.
R&D in Japan, 1973, p. 44-45.

Table 6

RESEARCH EXPENDITURES PER RESEARCHER IN JAPAN, BY SECTOR
(In 10,000 yen)

Year	Industry	Research Institutes	Universities
1961	355	237	133
1965	386	337	243
1968	611	476	279
1969	668	551	301
1970	740	647	348
1971	794	780	395
1972	837	917	383

SOURCE: *R&D in Japan, 1973*, pp. 57, 61, 65.

Table 7

PERCENTAGE EXPENDITURES ON R&D BY ITEM, 1972

Sector	Wages and Salaries	Materials	Fixed Assets	Other Expenses
All sectors	46.6	16.5	20.7	16.2
Industry	45.3	19.5	17.4	17.8
Research institutions	39.2	11.8	33.7	15.3
Universities	57.9	9.3	21.2	11.6

SOURCE: *R&D in Japan, 1973*, pp. 48-49.

RESEARCH AND DEVELOPMENT IN JAPAN
OVERALL BUDGET AND MANPOWER

Footnotes

1. Science and technology includes natural science, engineering, agriculture, and medical science.

2. Our statistics are in current yen, not taking into account the rate of inflation in Japan. For converting to U.S. dollar figures, we use 360 yen = $1 for the period through 1971, 300 = $1 for 1972 and after, considering this a fair long-term value. By using 360 = $1 for the late 1960's, we are undervaluing the expenditure on R&D.

3. Figures taken from: *Science Indicators, 1972*, National Science Board, 1973, p. 102. We are using these figures at their face value. We have not attempted to check how definitions of R&D expenditures vary between countries.

4. See OECD, *Reviews of National Science Policy, Japan*, 1967, p. 67, showing which public corporations are in which sector.

5. National universities are supported largely by the national government, public universities primarily by local (municipal and prefectural) government, and private universities largely from private sources.

6. Figures here and below are taken from Summary Table 3, *R&D in Japan, 1973*, p. 50.

7. By basic research we mean research undertaken primarily for the advancement of scientific knowledge, with no specific practical application in view. Applied research is research undertaken primarily for the advancement of scientific knowledge, with a specific practical application in view. Developmental research is the use of available results of basic and applied research directed to practical ends.

8. *R&D in Japan, 1973*, Table 11, p. 29.

9. *Technocrat*, January, 1974, p. 93.

10. *Science Indicators*, 1972, Table 14d, p. 110.

11. A regular research worker is one who has a university degree or equivalent and 2 years or more of research experience and who conducts research. Researcher will be used in this sense throughout the report.

12. The definition of researcher varies from country to country, and these figures should only be interpreted qualitatively.

B. SCIENCE POLICY IN JAPAN

Japan has a long tradition of a strong governmental role in science and technology. Through "administrative guidance" *gyōsei shidō*,* licensing restrictions, and fiscal policies the Japanese bureaucracy is in a position to exert a decisive influence over the direction of the Japanese technological effort and to affect major R&D decisions of industry. The impact of the government is particularly pronounced in the university and research institution sector, where government funding plays an important role and many of the personnel have the status of government employee.

1. Institutional Framework

A great variety of agencies and institutions play a role in government science policy.[1] The principal actors are briefly characterized below. It should be noted, however, that the jurisdictional lines suggested by our summary description of the institutional framework are not always as neat. There is ample evidence of rivalry among the various organizations concerned with science policy and frequently political factors loom larger than administrative efficiency as the criterion for jurisdictional decisions or the allocation of funds for research and development.

The *Science and Technology Agency* (STA) is one of the external organs of the Prime Minister's Office, but has some bureaucratic clout since it is headed by a cabinet rank director. In theory at least, it is responsible for the coordination of fundamental government science policy, for governmental research and for the preparation of the overall research budget. However, it has no control over the important university sector, which is the domain of the Ministry of Education. STA supports research at several national laboratories such as the National Aerospace Lab (NAL) and at "corporations under special charter" such as the Japan Atomic Energy Research Institute (JAERI), and the National Space Development Agency (NASDA). Thus it

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*Though frequently used this is not a legal term in the strict sense. "Administrative guidance" can take various forms, ranging from encouragement and suggestions of an unofficial nature, to warnings, official requests or instructions.

is largely responsible for the broad national projects in such areas as space and nuclear energy research. In the latter field it has a virtual monopoly. But the STA has direct control of a relatively small percent of the government science budget (about 13%). The principal sources of funding are the various ministries.

The *Ministry of International Trade and Industry* (MITI) has the primary responsibility in areas of industrial science policy. Its Agency for Industrial Science and Technology (AIST) administers sixteen laboratories and research institutes and coordinates the "big projects" sponsored by MITI under the national R&D program (see next section). The research institutes include the Electro Technical Laboratory, the Mechanical Engineering Laboratory, the National Chemical Laboratory for Industry, the government Industrial Research Institute, and the Fermentation Research Institute. We will examine MITI in more detail below in Section 2.

The *Ministry of Education* through its Education Bureaus and the Science and International Affairs Bureau has responsibility for all research carried out in the national, i.e., government-operated universities, and for about 40% of government R&D expenditures. It will be examined in more detail below in Section 3.

The *Ministry of Transportation* has jurisdiction over the Ship Research Institute, the Meteorology Agency, and the Railway Technical Research Institute.

The *Ministry of Posts and Telecommunications* has responsibility for the three public communications corporations, NHK, KDD, and NTT, and through them for their important research institutes.

The *Ministry of Health and Welfare* is charged with responsibility for research institutes in the medical field. Several other ministries including Agriculture, Construction, and Labor also have their own research institutes.

The *Science Council of Japan* (SCJ) is an advisory body attached to the Prime Minister's Office. Its 210 members are elected by the research community with about 200,000 people having voting rights. Since it includes people from human and cultural sciences, and since its membership differs sharply with the (conservative) Liberal

Democratic Party in its political outlook, this body tends to play only a subordinate role in the formulation of policy in areas of natural science and technology.

The *Council for Science and Technology* (CST) is responsible for advising on broad national science policy. Its membership includes the Prime Minister, the Ministers of Education and Finance, the president of SCJ, the directors general of the Economic Planning Agency and the STA, and five other individuals appointed by the Prime Minister. Like most Japanese advisory bodies, it is heavily dependent on the government bureaucracy for administrative support, supplied in this case by the STA. Evidence suggests that this high-level committee actually is satisfied with ratifying the decisions reached by consensus at lower levels.

The *Ministry of Finance*, through its budget responsibilities and its control over tax policy, and in conjunction with the Bank of Japan (BOJ) over foreign exchange, plays a major, if indirect, role in science policy as it relates to both private and public sectors. Whereas MITI tends to promote vigorously any program that seems to serve the interests of industry, the budget officials of the Finance Ministry traditionally are feared as meticulous scrutinizers of budgetary requests, thus serving as a balance to the more expansion- and expenditure-minded economic ministries. (For example, Japan's Sunshine Project [for new energy R&D] located in MITI saw recently its cherished plan for a national energy research institute ruthlessly deleted by the Ministry of Finance's Budget Bureau.)

2. Government-Industry Interaction

The Ministry of International Trade and Industry (MITI) plays the primary role in promoting industrial technological development. It has very close ties to the industries with which it deals. Many of its top-level administrators move after retirement into the higher echelons of business enterprises, and people in industry, both administrative and technical, take leaves of absence to join MITI's research laboratories for short periods of time.

Of special importance in policy making in AIST is the Industrial Technology Council, an advisory organ that draws on experts from all areas of Japanese science and technology, including many representatives of industry.[2] The Council is subdivided into sections and working groups which cover the entire range of MITI's jurisdiction.

Through AIST, MITI supports technological developments by private industry and implements R&D projects in its own associated laboratories. Of particular importance is MITI's National Research and Development Program, established in 1966 to focus funds and manpower on special "big projects." These projects aim at developing technologies that fulfill five requirements: (1) They must be urgently needed; (2) they must have a widespread effect; (3) risk must be so high, because of the large financial sums and prolonged research required, that industry would not develop them by itself; (4) the targets must be clearly defined and accompanied by a definite plan; (5) they must require the concentration of the efforts of the several sectors of performance.[3] These projects administered by AIST receive substantial funding from MITI (often several million dollars per year), and research is carried out in both industrial and government research labs. Currently the program includes projects on Magneto-Hydrodynamic generators (MHD), sea water desalting, electric vehicles, technology for automobile traffic control and for recycling resources. The typical time period for these projects is six years.

Industry is also expected to make major financial contributions to these projects. The government labs involved are not just those associated with MITI. For instance, the National Aerospace Lab, associated with STA, is collaborating with Ishikawajima-Harima Heavy Industries (IHI) on the jet engine project.

Not all of MITI's major projects are part of the National Research and Development Program. Such projects as the construction of a hydraulic model of the Seto Inland Sea for use in water pollution studies receive substantial funding (over $3 million in Fiscal Year 1972) but do not fulfill the requirements of being long term and requiring substantial cooperation.

MITI is not alone in sponsoring projects that involve industry and a cross-section of research institutes. There is significant

industrial participation in the nuclear energy, ocean development, space, and environment efforts. The coordination of these efforts is in the hands of the STA in the first three cases, and the Environment Agency in the last. But a great deal of responsibility often lies with other ministries. It would be interesting to study a few cases in detail to try to understand the process of accommodation--or in some instances non-accommodation of interests. (The Ministry of Education reportedly has prevented university participation in certain MITI and STA projects, probably because of jurisdictional problems).

A major force on the industrial side of the government-industry interaction is Keidanren (Federation of Economic Organizations). The other Big Four business groupings, generally coordinating their policies and economic strategies, are Nissho (Japan Chamber of Commerce), Nikkeiren (Japan Federation of Employers Associations) and the policy issue oriented Keizai Doyukai (Japan Committee for Economic Development). The Keidanren, representing Japan's largest business interests, interacts with the various ministries and agencies in deciding the involvement of industry in priority research projects. For instance, the Space Activities Promotion Council of Keidanren interacts strongly with governmental agencies in the space program. The same is true of the organization's Energy Committee.

As we have seen above, direct government support of industrial R&D is small, constituting only 2.6% (about $90 million) of all funds spent on R&D by private industry. However, these direct subsidies have been focused and have played a large role in certain priority areas such as computers and superconducting technology in recent years, and fermentation technology in the late 1950's.

More important, however, have been non-subsidy areas of control. As we will see below, technological imports have played a large role in the development of Japanese technology. These imports were controlled by the government under the 1950 Foreign Investment Law until 1968 when most areas were liberalized under pressure from Japan's trading partners, especially the OECD.[4] A more extensive discussion of the government attitude toward technology importation will be

presented below. Suffice it to say at this point that the government could and did reject the importation of technologies if they were not felt to be in the national interest. MITI also aided in the negotiation of licensing agreements, often placing the full power of the Japanese government behind the Japanese companies negotiating with foreign giants, such as IBM. The Japanese were thus able to get the best deal possible on foreign technology.

The government also employs fiscal measures to aid industrial R&D.[5] One measure allows a 25% depreciation writeoff in the first year of life of research equipment.

Loans are also available from the National Technology Promotion Fund of the Japan Development Bank. These are more often for the application of new technologies and not directly related to R&D efforts.

Government-industry interaction has been important to Japanese science and technology. But this is an area that is difficult to quantify. Emphasis on the meager data available may lead to an underestimation of this interaction. The government's attitude has been to sponsor indigenous technology, while making use of foreign technology to conserve scarce R&D resources. Firms such as Fujitsu in the computer field, who have largely developed their own technology, receive favored treatment from the government. "Fujitsu has participated in all major joint computer projects initiated by MITI and has always held an enviable position in them."[6] Fujitsu also has a major share of government and educational institution computers in Japan.

Government involvement has not been universally acclaimed by industry. Sony, the consumer electronics giant and somewhat typical of Japanese companies in its management strategy, believes this involvement spoils the big companies.[7] It is generally true that major enterprises do play a larger role in many government sponsored projects. Taking part in these projects is a matter of prestige for the companies involved, especially in such areas as space and nuclear energy, and the government recognizes the larger support these firms can give to R&D--as well as the political clout these companies wield.

3. University Science Policy

The Ministry of Education is primarily responsible for research and development in the universities. 157 billion yen (about 55% of the federal government support of R&D) in 1972 went to the national universities, 99% of the support for R&D in these universities.

The largest share of this money was distributed to each *koza* or university chair in fairly equal amounts. A *koza* will typically have a professor, an associate professor, two assistants, and two graduate students. An experimental *koza* might receive slightly more than a theoretical *koza*. After overhead and salaries a *koza* in, say, experimental polymer chemistry would have about 1.2 million yen (or $4,000) left for actual research expenses.

The Ministry also dispenses substantial sums for special projects and purposes. These are of four types: grants in aid for scientific research; grants in aid for scientific experiments; funds for publication of research results; grants in aid to private universities for research equipment. These funds allow priority areas to be selected and funded at a higher level.

The university research system has been the subject of a great deal of debate in Japan. Many feel the *koza* system is too inflexible, especially when interdisciplinary research must be carried out. The *koza* is felt to be best suited to vigorous attacks on special problems, but not for inter-disciplinary problems that cross *koza* lines. The government is presently creating Tsukuba University 75 km outside of Tokyo, where the faculty or *gakukei* system is being adopted. A large number of associated research institutes in such areas as high energy physics have also been placed there. The hope is that this will allow greater flexibility in the system. (One might also note that the AIST has introduced the group research system in its research institutes on a trial basis, again aiming for greater flexibility.)

One might also mention cooperation between universities in the area of cancer research. This "invisible" research organization coordinates the efforts of the various university groups involved in cancer research.

Overall support for research in the universities is low. A large amount of manpower works without the modern equipment available in industrial laboratories. Since generally support is fairly equal for different scientific fields, some of the more glamorous and expensive fields such as high energy physics especially suffer. Fields such as ferromagnetism, applied microbiology, and polymer chemistry may be relatively well funded, though certainly not by international standards.

One should also mention that the Ministry of Education has been very protective of its control over the national universities.[8] As mentioned earlier, it has resisted the involvement of universities in the research projects of other ministries. On the other hand, it has been a major force in trying to increase the importance of basic research, though its efforts have not met with success so far.

The interaction between industry and university research is a point of some friction for the national universities, since the professors are by law employees of the government. The extent of academic consulting with business is apparently at the discretion of each faculty member. But it is certainly not encouraged, in contrast to faculty consulting with government agencies. Nevertheless, it is extensive in such areas as marine engineering, polymer chemistry, and pharmaceuticals. There is little direct support for education, especially in the national universities, but contacts are maintained via personal relationships. Former students do return to their *sensei*, or professor, to find out about research currently going on in his laboratory, and professors do accept gifts of equipment if they are made available.

SCIENCE POLICY IN JAPAN

Footnotes

1. See: OECD, *Reviews of National Science Policy, Japan*, cited, pp. 81-95; UNESCO, *Science Policy and Organization for Research in Japan*, Paris, 1967; OECD, *The Industrial Policy of Japan*, Paris, 1972; Science and Technology Agency (Kagaku gijutsu Cho), *Kagaku gijutsu hakusho* (Science and Technology White Paper), Tokyo, 1974; Administrative Management Agency, Prime Minster's Office, *Table of Organization of the Government of Japan*, Tokyo, 1974; Institute for Defense Analysis, Nathan N. White, *Research and Development in Japan* (Paper P-926). Washington, D.C., 1973.

2. Shimada, J., "Problems Concerning the Organization and Operation of R&D of Large-Scale Industrial Technologies," *Technocrat*, January 1974, p. 85.

3. *Ibid.*

4. Areas not liberalized included the five OECD Article III items (aircraft arms, ammunition, atomic power, and space development), plus electronic computers and petrochemicals.

5. OECD, *The Industrial Policy of Japan*, cited, p. 88.

6. U.S. Department of Commerce, *Japan: The Government-Business Relationship*. Washington, D.C., 1972, p. 89.

7. Gregory, Gene, *IEEE Spectrum*, "Why Japan Succeeds," March 1974, p. 69.

8. Shimada, J., *Technocrat*, January 1974, p. 86.

C. MANAGEMENT OF R&D IN JAPAN

1. Business Decision Making and Management Philosophies

Management of R&D is an area that is apparently in a state of flux as the Japanese increase their expenditures on R&D in all sectors.[1] We have received various opinions as to how goals are set in industry. Generalizations here may be dangerous.

Certainly the consensus approach to decision making which prevades all levels of Japanese government and industry plays an important role. Long-range goals must involve the executive management, the R&D managers, and the researchers themselves. Whether a particular short-term project is funded may depend on convincing one influential man of its importance. At some companies, such as Sony, goals are set by top-level management. It is also claimed that it is a great deal easier to get support for research if similar research has been initiated elsewhere, especially in the U.S.

In all areas because of the group decision making process, middle management is perhaps most important (as it is in Japanese government agencies). It is they who must be convinced of priorities, and their decisions are often merely ratified by top management.

Some people have claimed that the large firms in Japan are not much different from those in the U.S. in their approach to R&D, especially the large electronics firms. If true, this may be a reflection of the close ties of many of the major firms to U.S. companies.

The Japanese are said to lack the small innovative firms. Sony certainly once was one of these. Back when it single-handedly developed the transistor radio in the 1950's, it committed essentially all of its R&D resources to this development. The virtual absence of small innovative firms in Japan is connected to such practices as lifetime employment in industry, which makes it difficult to get the people to start a new enterprise. One does not have the mobility in scientific manpower in Japan that one has in the U.S.

NEC (Nippon Electric Company) provides another example. There the management philosophy is one of setting long-range goals that are very ambitious with relatively low probability of being obtained. Short-range

targets are also set that are challenging but reachable and of practical importance. In the area of optical communications, the long-term goal is a viable optical communications system. In the short term, some of the glass fibers developed by NEC and Nippon Sheet Glass are used in medical equipment such as cystoscopes. In optical information processing the long-term goal is an optical memory; the short term involves developing optical input/output devices that would have applications in the area of publishing among others.

One problem of R&D management in Japan is the relative meagerness of resources in comparison with some of the foreign giants. Japanese companies must be selective in the areas they choose to pursue. Because of their more stringent budgetary constraints, they must pursue far fewer leads than do their American counterparts.[2] This means that a selection of the potentially most fruitful areas must be made. This early selection may mean they are less likely to provide breakthroughs, but more likely to find unusual developments in areas where only the cream has been skimmed by the giant laboratories. The Japanese do have a reputation for doing much better developmental work than basic research, and this early selection could be a factor.[3]

Concentrating a greater effort in development is a management philosophy appropriate to a low level of expenditures on R&D. Basic research on new materials and techniques is a much more risky undertaking. Of course the payoffs can be higher also.

The group decision-making process which requires consensus on whether to market a development from the research laboratories can also cause problems in areas of rapidly changing technology where a premium is placed on the rapid introduction of innovations. Consensus is more difficult to obtain if one does not have successful models to point to, "if no trail has been blazed to provide a focal point around which consensus can form."[4] The process of obtaining a consensus means that fewer mistakes are made. Products are not introduced for which there is no market. The American electronics industry, for example, is much quicker at getting new electronic devices incorporated into equipment than its Japanese counterpart.[5] This means there will be a greater number of mistakes made, but the strategy has been successful for the U.S. electronics industry as a whole.

The problem of what to do about research budgets during times of slow economic growth also confronts Japanese industry on occasion. The two years when expenditures on R&D in the industrial sector grew most slowly in the 10 years between 1963 and 1972 were 1965 and 1971, the two years when Japan's real GNP growth was smallest.[6] This tendency to try to economize on R&D expenditures during times of economic stagnation may have importance for the present moment in Japan. It will be worth watching whether Japanese industrial R&D expenditures have kept up with the rapid inflation rates in Japan over the last year and a half.

2. Management of Large-Scale Projects

In the area of large-scale projects where the R&D resources of a variety of groups, often from all three sectors of performance, must be coordinated, the Japanese do not have the experience of other developed countries, and they have not been particularly successful so far in managing these projects.

The Japanese are very aware of the lack of a systems engineering capability, and have frequently come to such organizations as Rand for assistance in developing their capabilities. It is the opinion of many scientists that success in this respect will be crucial to Japanese efforts in space, nuclear energy and other energy areas. At the moment these efforts are often fragmented, with no person or group clearly in charge. The large number of industrial groups taking part in the efforts due to their prestige value means that coordination is essential. (The example of the Japanese satellite program was mentioned at Hughes, where it was said that the Japanese approach was not the way to build a highly reliable sophisticated piece of equipment.)

MANAGEMENT OF R&D IN JAPAN

Footnotes

1. Tsuneo Fujita and Delmar Karger, *MGT. Int. Rev.*, *12*, "Managing R&D in Japan," No. 1, 1972, p. 65-73.

2. IBM's $730 million R&D budget for 1973 is larger than the entire Japanese electronics and communications sectors' research budget of 165 billion yen ($550 million) in 1972.

3. Interview with John Myer, Hughes Research Labs. He expressed this opinion and commented on tendency to followership.

4. Allison, Graham, *The Computer Industry in Japan and its Meaning for the U.S.*, "Government and Corporate Structure," National Research Council, 1973, p. 69.

5. Private communication, G. P. Lemberg, V.P., Quantum Science Corp.

6. See Table 2-2, *R&D in Japan 1973*, p. 48. 1971 growth of industrial R&D expenditures was 8.77%, approximately the inflation rate. 1965 - 3.5%.

D. THE INDUSTRIAL RESEARCH EFFORT - EXPENDITURES AND MANPOWER BY INDUSTRIAL SECTOR

We have already seen that the industrial sector is the focus of Japanese research efforts, with approximately two-thirds of the total R&D effort concentrated here.

Within the sector there is further concentration of the effort.[1] In 1972 the five firms in the industrial sector with the largest R&D budgets accounted for 16.5% of all expenditures, spending an average of 34 billion yen ($113 million) each. They employed 10% of all researchers in the industrial sector. Only 40% of this expenditure was for salaries, and expenditure per researcher for these firms was 14.1 million yen ($47,000), significantly above the industrial average and close to world standards.[2] These five firms are all in the auto and electrical machinery sectors.

The ten largest firms account for 25.7% of all industrial expenditures and are comparable in size to the entire research institution sector or to the entire university sector. The sixth to tenth largest firms average 20 billion yen ($67 million) in expenditures. The next 10 firms average 7.5 billion yen ($25 million) in research expenditures. Together the twenty firms with the largest research budgets account for 33% of the expenditures in the industrial sector. These twenty firms all come from five areas: electrical machinery, autos, steel, ships, and chemicals.

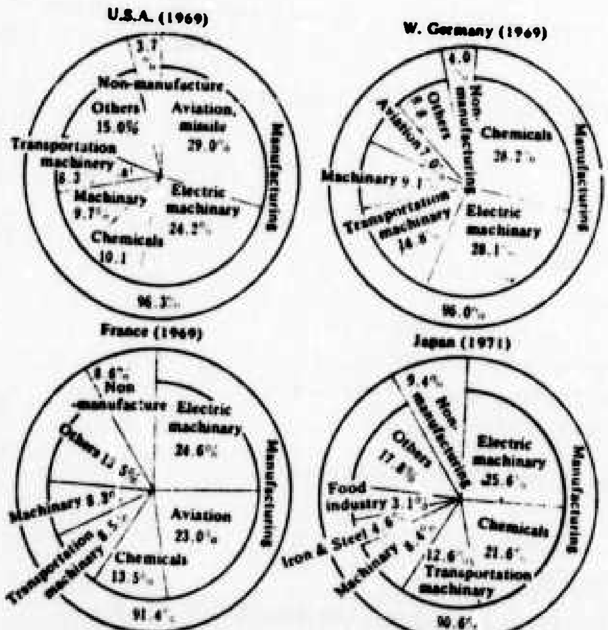
These areas are five of the six areas which had the largest shares of the industrial research effort in 1972. (Table 8). The sixth is the non-electrical machinery sector. The electrical machinery industry spent 26.5% of all industrial R&D expenditures in 1972, with chemicals (19.1%), transportation machinery (15.7%), non-electrical machinery (6.4%), and steel (4.0%) also having significant shares. These shares have changed over time. Such industries as steel, non-ferrous metals, and industrial chemicals have shown the sharpest drop in percentage share since 1961, while pharmaceuticals, precision machinery, and motor vehicles have been among the industries whose shares have increased.[3] This sort of shift away from sectors where the technology is relatively stable toward areas where technology is rapidly developing is characteristic.

Table 8

EXPENDITURE ON R&D BY INDUSTRY;
PERCENTAGE OF THE TOTAL EFFORT FOR EACH INDUSTRY, 1961-1972

	1961	1966	1972
All Industries	100.0	100.0	100.0
A. Agriculture, Forestry & Fisheries	.2	.1	.1
B. Mining	1.6	1.4	.6
C. Construction	2.0	1.4	2.5
D. Manufacturing	90.7	92.0	91.2
1. Food	2.9	3.2	2.8
2. Textile Mill Products	3.1	2.6	1.3
3. Pulp and Paper Products	1.1	1.1	.8
4. Publishing and Printing	.2	.4	.5
5. Chemical Products	22.5	23.6	19.1
a. Industrial Chemicals	14.7	13.2	8.9
b. Oils and Paints	1.7	2.5	2.0
c. Drugs and Medicines	4.1	5.4	5.3
d. Other Chemicals	1.9	2.4	2.8
6. Petroleum and Coal Products	1.7	1.0	1.4
7. Rubber Products	1.6	1.4	1.4
8. Ceramics	2.0	2.5	2.1
9. Iron and Steel	6.1	5.2	4.0
10. Non-Ferrous Metals & Products	3.9	3.5	1.8
11. Fabricated Metal Products	1.1	1.2	1.8
12. Machinery, Except Electrical	5.3	7.1	6.4
13. Electrical Machinery	23.8	22.3	26.5
a. Electrical Machinery Equipment & Supplies	10.5	8.7	10.7
b. Communication and Electric Equipment	13.3	13.6	15.8
14. Transportation Machinery	12.0	11.9	15.7
a. Motor Vehicles	8.7	10.2	11.1
b. Other Transportation Machinery	3.3	1.7	4.6
15. Precision Machinery	1.6	2.1	2.7
16. Other Manufacturing	1.8	3.0	2.9
E. Transport, Communication, and Public Utilities	5.5	5.1	5.5

SOURCE: *R&D in Japan, 1973*, p. 56.



Source: Report on the Survey of Research and Development in Japan
Bureau of Statistics, Office of the Prime Minister

SOURCE: *Technocrat*, January 1974, p. 95. Reproduced by permission of Fuji Marketing Research Co., Ltd.

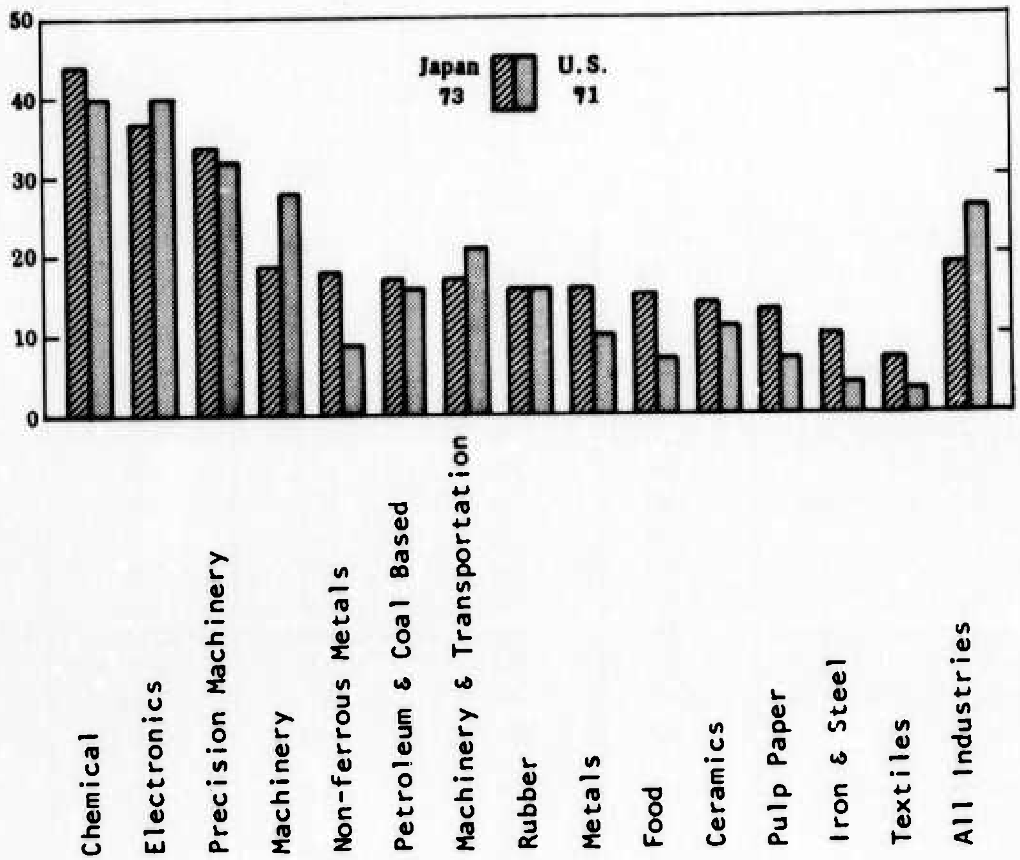
Fig. 1--Breakdown of industrial research expenditures in 4 nations

Table 9

MANPOWER AND EXPENDITURES IN THE INDUSTRIAL SECTOR, 1972

	Researchers	Researchers/ 10,000 Employed	Expenditures on R&D (Billion yen)	Expenditures per Researcher (Million Yen)	Expenditures as a Percentage of Sales
All Industries	124,795	185	1044.9	8.37	1.30
A. Agriculture, Forestry & Fisheries	172	41	1.2	6.76	.18
B. Mining	621	82	6.7	10.81	.61
C. Construction	2,951	85	26.3	8.91	.30
D. Manufacturing	117,544	229	953.2	8.11	1.52
1. Food	5,129	149	29.3	5.71	.43
2. Textile Mill Products	1,923	72	13.8	7.19	.62
3. Pulp and Paper Products	1,380	125	8.4	6.08	.51
4. Publishing and Printing	637	59	5.4	8.41	.36
5. Chemical Products	26,207	441	199.2	7.60	2.34
a. Industrial Chemicals	11,601	365	93.4	8.05	1.86
b. Oils and Paints	4,386	683	21.2	4.84	2.30
c. Drugs and Medicines	6,419	519	55.0	8.57	4.26
d. Other Chemicals	3,801	428	29.6	7.78	2.43
6. Petroleum and Coal Products	886	168	14.9	16.86	.38
7. Rubber Products	1,862	155	14.5	7.76	1.48
8. Ceramics	3,023	142	22.1	7.32	1.03
9. Iron and Steel	3,600	99	41.4	11.49	.77
10. Non-Ferrous Metals & Products	1,856	179	18.9	10.16	.99
11. Fabricated Metal Products	3,232	157	18.5	5.71	1.01
12. Machinery, Except Electrical	10,242	186	67.4	6.58	1.43
13. Electrical Machinery	36,789	367	276.7	7.52	3.34
a. Electrical Machinery Equipment & Supplies	17,415	338	111.8	6.42	2.74
b. Communication and Electric Equipment	19,374	398	164.9	8.51	3.94
14. Transportation Machinery	10,587	170	163.9	15.48	1.83
a. Motor Vehicles	6,918	192	115.6	16.71	1.95
b. Other Transportation Machinery	3,669	140	48.3	13.17	1.60
15. Precision Machinery	5,193	344	28.1	5.42	2.64
16. Other Manufacturing	4,998	150	30.7	6.15	.75
E. Transport, Communication, and Public Utilities	3,507	31	57.6	16.42	.66

SOURCE: *R&D in Japan, 1973*, p. 52, 53, 54, 57, 58.



SOURCE: *R&D in Japan, 1973*, p. 32.

Fig. 2--Number of researchers for each 1,000 employees in major industries in Japan and the United States

The breakdown of industrial research expenditures in Japan by industry differs from the U.S. and French breakdowns basically in the high priority given to aviation and missile research in those countries (see Figure 1). One also notes that West Germany has the industrial profile closest to that of Japan. Neither Japan nor Germany emphasizes military-related R&D to the extent of France or the U.S.

Another major difference with the U.S. is in the scale of the R&D efforts of industry. Single large firms in the U.S. often spend as much as entire industries in Japan. The budget for the *Bell Laboratories* in 1974, *$536 million*, is *comparable to the $550 million* spent by the entire Japanese electronics and communications industry in 1972. IBM's $730 million and GE's $845 million research budgets for 1973 dwarf those of their Japanese rivals. Only $110 million was spent by Japanese industry on computer-related R&D in 1972. Nippon Electric, which is not involved in as wide a variety of research efforts as GE, had an R&D budget of only $45 million in 1973. Dupont's $256 million R&D budget for 1973 was comparable to that for the ten largest chemical firms in Japan combined, $289 million in 1972. Clearly, Japanese Industry will be able to undertake far fewer research projects than its American rivals. It will also be unable to devote the amount of resources to a single development that for instance IBM devoted to its 360 series of computers or Xerox is presently devoting to its 9200 system.

The distribution of manpower between the different industrial sectors follows the pattern of the distribution of expenditures. Some sectors do have significantly higher expenditures per researcher, including transportation, petroleum and coal products, steel and non-ferrous metals, all sectors for which wages make up a smaller than average percentage of researcher expenditures (Table 9).

Researcher intensity for the individual sectors compares favorably with researcher intensity in the U.S. (see Figure 2). The industries in both countries that are most researcher intensive are chemicals, electrical machinery, and precision machinery. The number of researchers per 10,000 persons employed has been growing at a rate of 5% per year between 1968 and 1973 for the whole manufacturing sector

(Table 10). The transportation machinery, precision machinery, and electrical machinery sectors showed particularly rapid growth in this indicator of R&D intensiveness.[4]

However, expenditures as a percentage of sales, which overall was only 1.3% in Japan in 1972, are significantly lower than in the U.S. (Figure 3) in most industries. This is especially true of electrical machinery, chemicals, precision machinery, and transportation machinery. In areas like iron and steel the two countries are closer together in the low percentages of sales devoted to R&D.

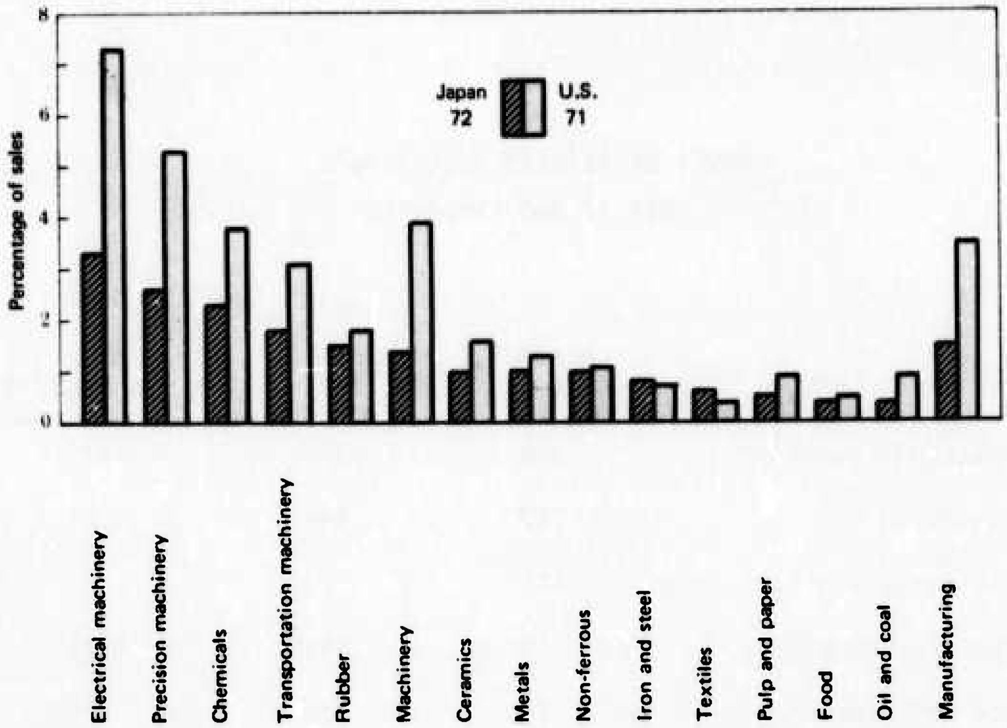
The statistics quoted above can obscure the essential points we wish to make in this section. First, R&D in the industrial sector is dominated by the large firms in Japan. Secondly, R&D is concentrated in relatively few sectors: electrical machinery, chemicals, and transportation machinery. Third, the main difference in the profile of its R&D expenditures with other developed countries is the smaller emphasis on military-related R&D. Fourth, the scale of R&D efforts is significantly smaller than in the U.S. Fifth, expenditures on R&D as a percentage of sales are low compared to the U.S., while manpower per 10,000 employees is about the same. Sixth, this means that support per individual researcher is still low by U.S. standards. Finally, both manpower and expenditures have been increasing fairly rapidly over time in Japan, while industrial R&D expenditures and manpower have stagnated in the U.S.

Table 10

NUMBER OF REGULAR RESEARCHERS
PER 10,000 EMPLOYEES

	April 1, 1968	April 1, 1973	Ratio 1968/1973
Electrical Machinery	268	367	1.37
Chemicals	357	441	1.24
Transportation Machinery	119	170	1.43
Precision Machinery	236	344	1.46
Iron and Steel	80	99	1.24
Non-Ferrous Metals	200	179	.90
Non-Electrical Machinery	149	186	1.25
Ceramics	116	142	1.22
Rubber Products	139	155	1.12
Fabricated Metal Products	154	157	1.02
Petroleum and Coal Products	144	168	1.17
All Manufacturing	180	229	1.27

SOURCE: *R&D in Japan, 1973*, p. 53.



SOURCE: *R&D in Japan, 1973*, p. 28.

Fig. 3--Comparative Japanese and U.S. research expenditures as a proportion of sales in major industries

THE INDUSTRIAL RESEARCH EFFORT

Footnotes

1. Statistics here and below taken from *R&D in Japan, 1973*, Table 12.

2. U.S. industry spent $51,000 per researcher in 1971. Source: Table 15 (p. 110) and Table 18a (p. 112), *Science Indicators, 1972*, National Science Board, 1973.

3. Recall that these are shares of a rapidly increasing industrial R&D pie. R&D expenditures of all industries have expanded over the past ten years. Non-ferrous metals, whose share of the pie dropped most drastically, still tripled expenditures between 1961 and 1972.

4. Note the U.S. industry's researcher intensiveness has been falling since the mid-1960's. The overall fall was from 300 researchers per 10,000 employees in 1965 to 240 researchers per 10,000 employees in 1970. See *Science Indicators, 1972*, National Science Board, 1973, p. 80 and 138.

E. GOVERNMENT RESEARCH BUDGET

Public sources provided 27% of Japan's R&D funds in 1972, 432 billion yen (about $1.4 billion).[1] The total national government expenditures on R&D in science and technology was 374 billion yen (about $1.2 billion).[2] The difference presumably comes from local government support of public university research and research institutes associated with local government. We will be examining only the national budget below.

The national budget for science and technology R&D increased by a factor of 4.1 in the 10-year period between 1963 and 1972 (see Figure 4),[3] an average rate of increase of 17%. Overall R&D expenditures, public and private, increased by a factor of 4.9 in the same period. In 1971 and 1972 the government budget increased by 15.9% and 22.5% respectively, while industrial expenditures increased only 8.7% and 16.7% in the same years.[4] Thus, government may have been less affected by the "economic shocks" of this period. Further, the government budget for the promotion of science and technology, a subset of the total government R&D budget, continued to increase at a healthy pace in 1973 and 1974.[5] It grew to 210 billion yen in 1973, and 262 billion yen in 1974, increases of 24.6% and 24.7% respectively. These increases have at least kept up with the rapid inflation rate, and likely will exceed the increases in the industrial sector during this period, given the 1965 and 1971 experiences when industrial R&D expenditures stagnated during mild recessions.

The government research budget is distributed through the various Ministries and agencies. The budget-making process involves an accommodation of the interests of the different Ministries and agencies. The budget process passes thorugh five stages: "(1) inter-Ministry liaison conference, (2) Ministry-by-Ministry formulation, (3) across-the-board cuts by the Ministry of Finance, (4) eleventh-hour bargaining for partial restoration,,and (5) ultimate decision by the Cabinet conference."[6] The Diet approves the result with little change.

The largest share of the government R&D budget goes via the Ministry of Education to the national universities. This was 159 billion yen (42%) in 1972.[7] Federal government-owned research institutions, associated with the various ministries, and special corporations in the research

institution sector such as JAERI, PNC, and NASDA received 139 billion yen (37%) in 1972.[8] Industry received only 27 billion yen (7.2%) in the 1972 federal R&D budget.[9] The remainder went to support of R&D in local government research institutes, private research institutes, and public (local) universities.

The government takes responsibility for the broad national R&D efforts in such areas as nuclear energy, space, and ocean development. The budget for space and nuclear energy is outlined in Table 11. This may underestimate total spending in those areas since the expenditures are from the subset of the total budget, the "budget for promotion of science and technology." The two expenditures make up 46% of the 1974 "budget for the promotion of science and technology."

The defense R&D budget constitutes a very small fraction of the total government effort.[10] In 1969 total defense R&D expenditures were only 6.5 billion yen ($18.1 million at 1969 exchange rates). This was only 2.9% of the total federal R&D budget that year. Through the 1960's it was the item that grew slowest in the national budget, increasing from 3.2 billion yen in 1961.

In 1972 the total budget for environmental research was 9.1 billion yen.[11] In 1973 this expenditure grew to 14.4 billion yen. This reflects a growing concern with environmental matters in Japan.

We have not been able to obtain a breakdown of the budget for individual ministries in recent years. Two major items in the 1973 and 1974 budgets, which would probably be handled by MITI, were large scale industrial technology (8.4 billion yen in 1973 and 9.7 billion yen in 1974), and computer technology including hardware, software, and semiconductor devices (11.9 billion yen in 1973 and 19.7 billion yen in 1974).[12]

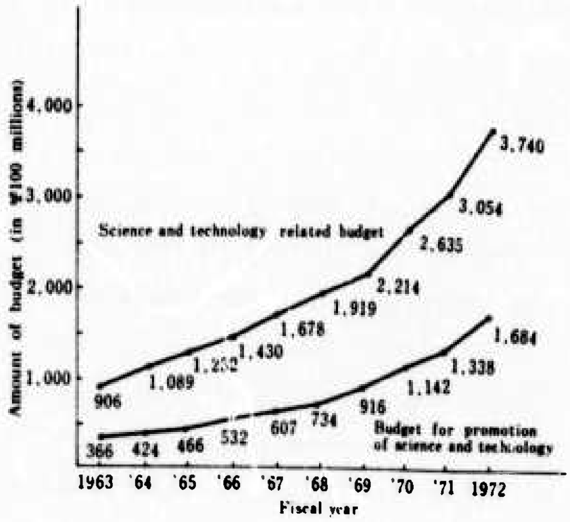


Fig. 4--Science and technology related budget

Table 11

GOVERNMENT EXPENDITURES IN BILLION YEN

	1971	1972	1973	1974
Atomic Energy	47.6	56.2	63.0	67.4
Space Development	12.4	20.6	32.4	52.2

SOURCES: *Summary White Paper*, 1972, p. 58 (Fig. 3-3).
Budget in Brief, 1974, p. 46.

GOVERNMENT RESEARCH BUDGET

Footnotes

1. *R&D in Japan, 1973*, Table 3, p. 50.
2. *Summary White Paper*, 1972, p. 56 (Fig. 3-1).
3. Source for Figure 4, *Ibid.*
4. *R&D in Japan, 1973*, p. 40.
5. *Budget in Brief*, 1974, p. 46.
6. OECD, 1967, p. 95.
7. *R&D in Japan, 1973*, p. 50. The 1972 White Paper, p. 57, says the National Universities got 148.2 billion yen in 1972 (40% of the total) (see Fig. 3-2). The discrepancy may be due to different definitions of R&D in the different agencies.
8. *R&D in Japan, 1973*, p. 30, Table 3.
9. *Ibid.*
10. White, *R&D in Japan*, p. 46, Table 10.
11. *Quality of the Environment, 1973*, Environment Agency, p. 239.
12. *Budget in Brief, 1974*, p. 46.

F. THE ROLE OF FOREIGN TECHNOLOGY[1]

1. The Changing Government Role in Technology Acquisition

Foreign technology has played an important role in Japanese post-war economic successes. It has been and continues to be imported (and often adapted and improved) in all sectors, and in significant quantities in most sectors.

These imports were under government control from the time of the 1950 Foreign Investment Law until 1968 when most areas were decontrolled. During the 1950's the government's role was most important.[2] MITI would periodically issue lists of technology it felt must be acquired. Each application for the importation of a technology had to be submitted for approval to MITI and to the Bank of Japan's Foreign Bureau, and later to the Science and Technology Agency (after its establishment in 1956). The rationale for the government control of licensing agreements was that this was a form of foreign investment which was in essence regarded as having a negative effect on Japan's balance of payments. Since presumably an up-to-date foreign technology would give a Japanese firm an advantage over its competitors, the rush to acquire foreign technology had to be regulated.

The Japanese government, through MITI, was able to concentrate the acquired technology in priority areas, that changed over time. This was a major instrument in MITI's hands for imposing their view of the appropriate structure for Japan's industry. At first emphasis was on such key industries as iron and steel, shipbuilding, and the public utilities. Later, government attention shifted to such new industries as motor vehicles, machine tools, electronics and electrical equipment, precision machinery, chemicals, synthetic fibers and plastics.[3]

Moreover the government could and did play a major role in negotiating the licensing agreements. If the cost was too high, the agreement would not be approved. This certainly aided Japanese companies in dealing with some of the American giants. Other tools, such as import quotas, could also be used by MITI in dealing with stubborn

foreign firms. Such was the case in the classic confrontation between IBM and MITI in the late 1950's, the result of which was the licensing of IBM's basic patents for a 5% royalty on sales in return for the right to a specified share of the Japanese market, as determined by MITI, plus other restrictions.[4]

In 1968 the control of the importation of technology was ended in all areas except the five OECD Article III items (aircraft, arms, ammunition, nuclear power, and space development) plus electronic computers and petrochemicals, regarded as key industries.[5] This decontrol was a part of the general program to decontrol foreign investment in Japan as it entered the first rank of economic powers and as its earlier balance of payments problems disappeared. (Former Prime Minister Tanaka played a key role in much of this decontrol while head of MITI.) Since 1968 import applications for liberalized technologies are submitted to the Foreign Bureau of BOJ and approved immediately if the royalty is less than $50,000 or within one month if greater than $50,000. Applications for imports in the seven categories on the controlled list are examined by the Foreign Investment Council on a case-by-case basis. "According to GOJ officials, no applications have been turned down since 196d" (to 1971).[6]

The remaining restrictions on the import of technology and on the manufacture under license of computer-related equipment were abolished on July 1, 1974.[7]

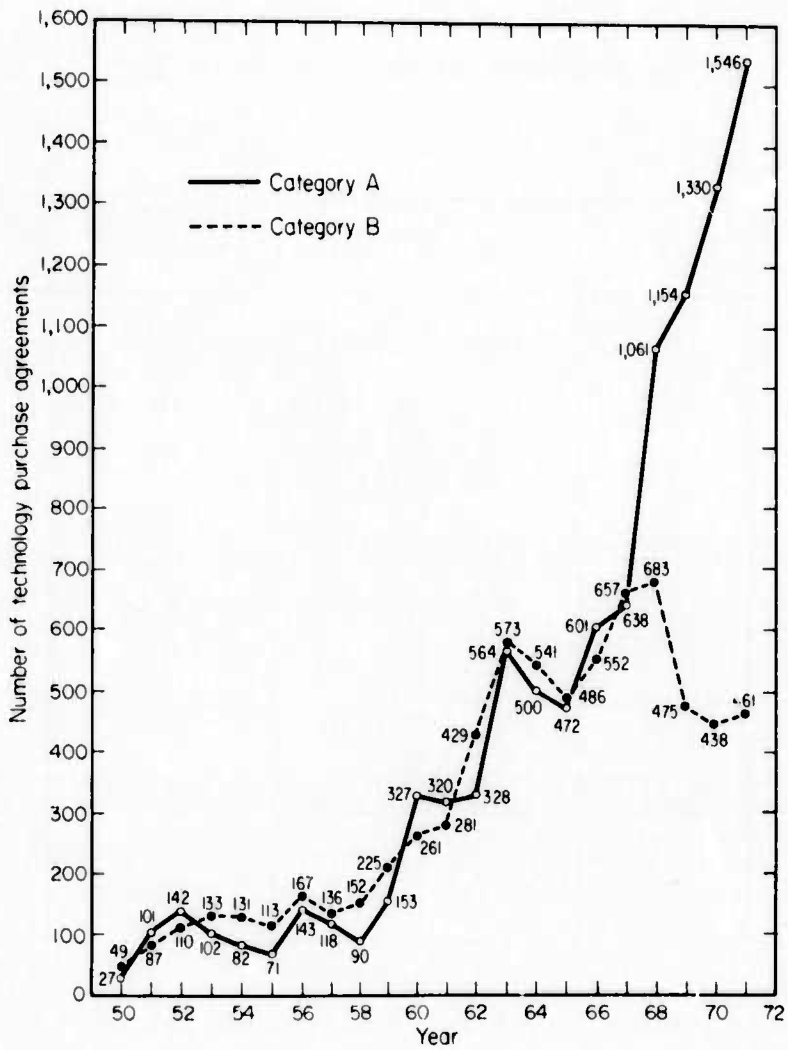
2. Statistical Overview: The Amount, Type, and Sources of Imported Technology

The Japanese identify two types of licensing agreement. The distinction is one of time period and of type of currency involved. Type A agreements have a contractual life longer than one year with the payment of royalties guaranteed to be made in foreign currency. Type B agreements extend for less than a year or call for royalty payments in Japanese yen. Type B agreements tend to be one-shot purchases of blueprints or prototypes.

Through 1971 there were a total of 9,870 type A cases of technological import, and 7,140 type B cases. (See Table 12 and Figure 5). These have shown a constant increase over time increasing from 320 cases of type A in 1961 to 1546 of type A in 1971. Payments have increased from $113 million (about 41 billion yen) in 1961 to $488 million (168 billion yen) in 1971. It is worth noting that the ratio of payments/industrial R&D expenditures was .25 in 1961, and .19 in 1971, an indication of the increasing emphasis on domestic R&D.

The United States has been the major source of Japan's technology (see Table 13). Almost 58% of the type A technology imports during the period 1950-1970 came from the United States. Other major sources have included West Germany (12%), the United Kingdom (7.5%), France (4.2%) and Switzerland (6.2%). The role of the Soviet Union as a source of Japanese technology has continued to be small throughout the period in question.

The areas where imports have concentrated in recent years have been machinery, chemicals, electrical machinery, and textiles (see Table 14). We unfortunately do not have statistics on the sources of the technology by area of technology.



SOURCE: T. Ozawa, *Japan's Technological Challenge to the West: 1950-1974*, MIT Press, 1974, p. 19. Reproduced by permission.

Fig. 5--Technology imports--number of contracts for the purchase of technology, Categories A and B, 1950-1971

Table 12

NUMBER OF NEW CASES OF IMPORTED TECHNOLOGY
AND PAYMENTS FOR IMPORTED TECHNOLOGY

	Type A	Type B	Total	Payments $1,000,000	Billion Yen
1950-1964	3068	3388	6,456	868	313
1965	472	486	958	167	60
1966	601	552	1,153	192	69
1967	638	657	1,295	239	86
1968	1061	683	1,744	314	113
1969	1154	475	1,629	368	132
1970	1330	438	1,768	433	156
1971	1546	461	2,007	488	168
Total 1950-1971	9,870	7,140	17,010	3,069	1,098

Note 360 yen = $1 except for last 3 months of fiscal 1971 (January 1-March 31, 1972) when the value 308 yen = $1 is used.

SOURCE: *Technocrat*, January, 1974, p. 98. By permission of Fuji Marketing Research Co., Ltd.

Table 13

SOURCES OF JAPANESE TECHNOLOGY IMPORTS (1950-1970), TYPE A AGREEMENTS

Country	1950 -1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	Total	% of Total
U.S.A.	658	200	187	202	355	274	265	329	388	602	598	746	4804	57.8
U.K.	34	10	16	13	36	47	40	46	57	105	108	108	620	7.5
West Germany	72	45	40	46	64	60	55	66	69	150	146	188	1001	12.0
France	34	5	10	8	25	15	21	33	29	37	62	73	352	4.2
Switzerland	81	18	22	25	29	61	-	-	-	-	-	-	520	6.2
U.S.S.R.	0	0	1	0	0	2	-	-	-	-	-	-	18	.3
Others	114	49	44	34	55	41	91	127	95	167	240	215	1003	12.0
Total	1023	327	320	328	564	500	472	601	638	1061	1154	1330	8318	100.0

SOURCES: 1950-1964 OECD, 1967.
1965-1970 State Department, A-857, October 20, 1971.
Ozawa, *Japan's Technological Challenge to the West*, p. 26.

NOTE: "Others" includes Switzerland and U.S.S.R. for the period 1965-1970, for which data could not be obtained.

Table 14

JAPANESE IMPORTS OF FOREIGN TECHNOLOGY
(Unit: Number of applications approved)

	1965	1966	1967	1968	1969	1970
By Major Industrial Categories						
Chemicals	195	247	292	362	264	361
Metals	71	129	156	169	101	91
General Machinery	339	409	363	516	563	470
Transport Machinery	37	30	36	66	75	77
Electrical Machinery	126	102	146	256	225	229
Textile	72	72	111	130	152	193
Foodstuffs	15	21	31	42	17	29
Construction	23	13	28	18	18	11
Others	80	130	132	185	214	307
TOTAL	958	1,153	1,295	1,744	1,629	1,768
Of which: A	472	601	638	1,061	1,154	1,330
B	486	552	657	683	475	438

A - Agreement term exceeding one year.
B - Agreement term expiring within one year.

SOURCE: Department of State, A-857, October 20, 1971.

3. Imitation and Improvement: Japan's Use of Imported Technology

Given this clear use of foreign technology, one must confront the question of imitation.[8] To what extent have the Japanese simply copied foreign technology? Have there been improvements? Could other nations have done as well? The claim generally made is that the Japanese industries, starting from a very low base, were able to modernize their industrial production by adding capacity using the latest foreign technology, that this technology was essentially copied, though often with improvements that increased the potential capacity.

The ability to make use of foreign technology should not be lightly regarded. To successfully "copy" one must possess basic know-how. If that is all you possess then you do try to simply duplicate the process at first. As more experience is gained, possible improvements may become clear. Over time the ability to develop one's own technologies may emerge, though this is a difficult step.

Quantifying the improvement of imported technology is very difficult. Nevertheless, improvements have been the rule. Rosovsky reports that Japanese businessmen have told him "that they have frequently succeeded in running a foreign process at up to 130% of rated capacity, simply by making a set of minor, though carefully considered improvements."[9]

Tsurumi has studied the period 1950-1964 trying to determine the extent of dependence on foreign technology.[10] He found that a great deal of Japan's R&D during this period was devoted to the absorption and renovation of licensed technologies.[11]

In 1961, 26% of Japan's 164 billion yen industrial expenditures on R&D ($456 million) was devoted to absorption of foreign technologies.[12] In 1964, the percentage was lower in nine of fourteen industries, perhaps an indication of greater ease in absorbing technologies.[13] License related R&D was important in all industries, especially the advanced industries such as chemicals, machinery, electrical and electronics machinery, and transportation machinery, where three-fourths of R&D was license related (see Table 15). These were also

Table 15

R&D EXPENDITURES: ABSORPTIVE, RENOVATIVE, INNOVATIVE

Industry	Absorptive a 1961	Absorptive b 1964	Renovative c 1964	Licensed Related b + c 1964	Innovative 1964
Textiles	2.0%	44.0%	34.5%	78.5%	21.5%
Lumber & Wood Products	-	4.2	8.0	12.2	87.8
Pulp & Allied Products	32.6	3.6	45.4	49.0	51.0
Printing & Publication Products	9.3	9.0	20.2	29.2	70.8
Chemicals	15.7	26.0	47.5	73.5	26.6
Petroleum Products	-	6.2	38.2	44.4	55.6
Rubber & Leather Products	45.0	46.0	25.0	71.0	29.0
Stone, Clay & Glass	15.1	5.8	37.3	43.1	56.9
Iron & Steel	17.0	7.5	37.5	45.0	55.0
Non-ferrous Metals	31.0	8.5	35.5	44.0	56.0
Fabricated Metals	24.3	8.9	40.1	49.0	51.0
Machinery	22.3	16.9	68.1	80.5	19.5
Electrical, Electronics & Telecommunications	46.8	24.4	48.1	72.5	27.5
Transport Machinery	18.5	10.6	60.9	71.5	28.5

SOURCE: Yoshihiro Tsurumi, *Technology Transfer and Foreign Trade: The Case of Japan, 1950-1966*, Doctoral thesis. Harvard University, June 1968, p. 219, 221, 223. By permission of the author.

the Industries where the greatest sums were spent on R&D. Further, these industries also had the highest percentage of sales of products with licensed related technology in 1964. (37% for chemicals, 37% for electronics products, 28% for electrical machinery, 14% for machinery, 51% for rubber products. One has to be careful of these figures. They are based on the industries' own judgments, and ways of calculating the percentage may have varied.)

Further in a 1963 MITI study of 1,362 technologies commercialized in Japanese industries between 1957 and 1962, it was found that 279 technologies were licensed (20.5%) but that capital expenditures for these technologies were 49.5% of the total, 630 million yen per technology, far in excess of the self-developed technologies (less than 200 million yen/technology).[14] This was attributed to the fact that imported technologies were far more advanced than self-developed technologies, and required greater technical adjustments. Self-developed technologies tended to be simple improvements on existing products and processes.

Japanese licensees mainly sought technologies that had been commercially successful in other countries.[15] The main reasons given for seeking imported technology in a 1966 MITI study of 917 firms with at least one type A licensing agreement were to develop the market position in Japan (61%), to strengthen international competitive strength (53%), lack of time to develop own technology and meet the competition at home (35%), to diversify product lines in a hurry (31%), to economize R&D expenses (24%).[16] (Recall this is industry talking about itself.) Further 45% of the firms felt forced to buy the use of foreign patents to avoid infringement of these patents in their own development work.

Management in 1964 basically was doing the expedient thing in a desire to solidify its competitive position without the uncertainty of gambling on its own original R&D according to Tsurumi.[17] Only 17% of R&D in 1961 was devoted to the development of new products. Basically the goals were short-term goals, although larger firms did display a longer-term outlook. (17% of R&D projects for firms capitalized at 10 billion yen or more had time ranges of five or more years.)

Licensing agreements tended to become self-perpetuating. Over 80% of a sample of 644 type A agreements in effect in 1966 were scheduled to be renewed, often essentially on the same terms.

This was the situation in the mid-1960's when Japanese industry was still spending less than a billion dollars a year on R&D. Certainly by 1971 when R&D had reached over $3 billion, the situation had changed. We unfortunately do not have a comparable MITI study to make use of. We do have the statistics given in Table 12 on the number of agreements and the money paid for foreign technology, but these can be misleading. First of all, the increasing use of foreign technology should not be surprising since as an industry's research capabilities increase it will have a greater capacity to absorb technology, and it will have increasing difficulties with patent infringement, causing licensing agreements.[18] It would be interesting to learn the pattern of licensing agreements that involve technical assistance, and the pattern of patent-only agreements and cross-licensing agreements. It is clear that cross-licensing today is becoming increasingly important, especially for technologically active industries. Fujitsu, for example, has cross-licensing agreements with IBM and TI among others. By 1971 there were 54 cross-licensing agreements compared to only three in 1965 (Table 16). Further one would also likely find the percent of patent-only agreements increasing and that of technical assistance agreements descreasing. That at least is the opinion of all sources, though statistics have not been obtained to back up these conjectures.[19]

We do have statistics on imported technologies for the year 1972 from the Japanese Bureau of Statistics.[20] These statistics cover 1207 new cases of technology import and 4776 continued cases for a total of 1559 firms. These firms performed 66% of all R&D in the industrial sector in 1972 (692 billion yen) and received 45% of all profits (3,373 billion yen).

First of all, most of the payments (159.5 billion yen) went for continued programs. Only 14.5 billion yen were paid as part of the new programs.[21] This may be an indication of the decreasing importance of the introduction of new technologies to Japan, relative to

domestically developed technologies. Most of the payments in the continued programs are for technologies previously transferred, and pay for patent rights. For instance, all integrated circuit producers must pay 10% of sales (2% to Western Electric, 4.5% to Fairchild, 3.5% to Texas Instruments) in royalties for the basic patents in this area, without deriving any new benefits from the licenses.[22]

Of the 798 new cases, 440 (55%) originated in North America, 356 in Europe (45%), and two elsewhere. Of the 4259 continued cases, 2,787 (65%) originated in North America, 1,454 (35%) in Europe and 18 elsewhere. This is consistent with the post-war pattern for sources of technology.

4. Availability and Cost of Foreign Technology for Japan

According to many reports the price for obtaining foreign technologies has been increasing in recent years. Foreign firms are demanding joint ventures, rather than simply selling know-how for royalties. Market restrictions written into the agreements in increasing numbers also hurt Japan's international competitive position.[23] In 1971 75.6% of all new type A agreements restricted the market of the Japanese partner. The most common restriction was to Japan or to Japan and Southeast Asia, and restrictions were fairly uniform across industries.[24] (See Table 17)

There is supposedly a greater reluctance to sell technology at all now that the Japanese have reached world technological levels. As one American executive said: "Fifteen years ago Japan was still an interesting market for our technology. They have their own capabilities now, so we will be more careful in selling our know-how. It is all right to provide some useful information if the full effect is good for you in terms of business, and if the licensee is behind technologically. This is no longer true (for Japan)."[25]

This may be one of the major reasons the U.S. has in the past been so generous of its technology to Japan. The U.S. has provided 57.8% of the technologies introduced between 1950 and 1970. In some cases the liberal licensing policies of U.S. firms have been determined by other factors. Western Electric has always been liberal in its

Table 16

CROSS-LICENSING AGREEMENTS AND JOINT R&D CONTRACTS BETWEEN JAPANESE AND FOREIGN FIRMS

Number of cross-licensing agreements, both Class A and Class B, including joint R&D contracts (the figure in parentheses indicates the number of joint R&D)

Industry	1963	1964	1965	1966	1967	1968	1969	1970	1971
Nonelectric machinery				1	7 (1)	4 (3)	5 (2)	3	11 (2)
Electric machinery		1	1	2	3	17	8	10	25
Metals and metal products				4 (1)		2 (1)		2	4
Chemicals	1		1	1	9 (1)	12	8	4	12 (3)
Others			1	1		6		7	2
Total	1	1	3	8 (1)	19 (2)	40 (4)	21 (2)	26	54 (5)

SOURCE: T. Ozawa, *Japan's Technological Challenge to the West: 1950-1974*, MIT, 1974, p. 127. By permission of MIT Press.

Table 17

MARKET RESTRICTIONS IMPOSED ON JAPANESE PARTNERS OF TECHNOLOGY AGREEMENTS IN 1971

Restriction	Electrical machinery	Nonelectrical machinery	Metals	Chemicals	Others	Total
No market restriction	62	133	14	62	60	331
Market restriction	138	356	61	186	285	1,026
Agrrements with restrictions (percentage of total restrictions)	69.0%	72.8%	81.3%	75.0%	82.6%	75.6%
Market permitted:						
Japan	22	90	25	83	146	366
Japan, S. Korea, Taiwan	4	26	3	12	17	62
Japan, S.E. Asia	24	164	13	43	83	327
Japan, S.E. Asia, Europe	10	3	0	1	0	14
Any country except the Communist bloc	6	14	0	14	4	38
Others	72	59	20	33	35	219
Total	200	489	75	248	345	1,357

SOURCE: T. Ozawa, *Japan's Technological Challenge to the West: 1950-1974*, MIT, 1974, p. 125. By permission of MIT Press.

licensing policy.[26] This originally was probably mainly due to the antitrust suit seeking to separate Western Electric from the Bell System in the 1950's, and the consequent desire not to appear to be monopolizing the semiconductor industry. Bell also did acquire access to important semiconductor development arising in other firms by licensing its technology. Similarly IBM has had a liberal licensing policy (at least since 1960), again perhaps in large part due to antitrust problems. These policies set patterns for industries. Firms such as Texas Instruments, and earlier IBM, who were reluctant to sell licenses, and instead sought direct investment opportunities, were often forced to sell patent licenses as a price for entry on the Japanese market.[27]

Other people have also pointed out the role of the State Department which has traditionally favored the export of U.S. technologies as a means of winning goodwill. Transferring aircraft technology in the 1950's and 1960's probably made the development of fighter aircraft more politically palatable in Japan, and allowed greater numbers of planes to be operated by the Japanese Air Self-Defense Forces than would have been the case if they had had to be purchased.[28]

In any case there are a variety of answers to why the sources of Japanese technology were willing to part with it. The remarkable thing may be the price at which the technology was sold, most often a royalty of between 1% and 5% of sales.[29] This technology had cost far more to develop. Apparently foreign firms regarded any royalties as a windfall, but also MITI played a major role in keeping this price in line through its veto power on licensing agreements. Much of the technology was not the latest development, but often five to ten years old, so that there was little fear of direct competition in most cases.[30] However, if the technology was transferred in an area of technology that was relatively stable, for instance the LD pure oxygen converter for steel or submerged-arc welding techniques for shipbuilding, the Japanese were soon offering direct competition to the source of technology.

5. Japanese Technological Information Gathering

The Japanese have gone about the importation of foreign technology in a systematic way. How have they obtained the necessary information? How do they monitor R&D in the U.S. and Europe?

The government has played a role in this activity. The Japan Information Center for Science and Technology (JICST), established in 1957 under STA, plays the role of translator and disseminator of foreign technical information.[31] MITI also provides information on foreign technologies. Since the Patent Office is a part of MITI, the most important new foreign technologies in a sense came to MITI.[32]

Furthermore, individual Japanese firms make use of the open literature, such as professional journals, trade journals, patent applications, and trade convention materials. There is an increasing tendency to permanently station scientific staff abroad. Fujitsu and Hitachi in the area of computers and JEOL (Japan Electron Optics Lab) in the area of scientific instruments are but a few of the firms with technical staffs in California. These staffs are responsible for monitoring the new developments in this country. In the area of computers, particular attention is paid to the new applications developed in this country.

The Japanese have also long been in the habit of sending large delegations to the U.S. and Europe to study the technologies available there. This is especially true of the start of major projects, such as the recent Sunshine Project, at the start of which a delegation visited such places as JPL in this country to learn about solar energy research.[33]

The long-term contacts between various Japanese and western firms also aid in the gathering of information. Lockheed and Kawasaki, Hughes and Nippon Electric, GE and Toshiba, Westinghouse and Mitsubishi, Union Carbide and Toyo Rayon, GE and Mitsui Chemical, Dow Chemical and Asahi Chemical, Babcock and Wilcox and Hitachi, and many others, have had long-term relations, often involving joint ventures, in some cases involving partial ownership. The large Japanese firms maintain close ties with many U.S. firms and this undoubtedly aids them in learning about new developments, although it may also hinder them if

one of their traditional partners is unable to deliver the needed technology.

Japanese industry also makes use of private information services and university contacts both in Japan and abroad. Many Japanese scientists have been educated in the U.S., or have come here as post-docs to work in one of the major university or industrial labs, often sponsored by their company or the government. American scientists also have spent time in Japanese industry as consultants, and it is not uncommon to find American personnel in positions of responsibility in R&D efforts. For instance, Honny Chemicals has employed Dr. John Wetzel, formerly of GE's Chemical Division, as a general manager of one of their research laboratories.[34] Japanese customers are among the major clients of such management information firms as Quantum Science Corporation, a Palo Alto based high technology management information firm.

Moreover, the large trading firms also maintain staffs in this country to monitor events here. In general, the individual Japanese firm uses as many of these services as it can afford. The larger firms will use the whole wide range of informants in gathering information and assessing how new developments may be employed.

THE ROLE OF FOREIGN TECHNOLOGY

Footnotes

1. Terutomo Ozawa has recently published a more extensive discussion of the role of foreign technology in post-war Japan, *Japan's Technological Challenge to the West, 1950-1974.* We have made some use of his statistical data to update some of our tables and figures, but the interested reader is referred to Ozawa for a different perspective on the themes of this section.

2. Tsurumi thesis (as on Table 15, p. 52), pp. 133-137.

3. *Ibid.*, pp. 136-137.

4. *Ibid.*, p. 139. Also, *Japan: The Government-Industry Relationship*, cited pp. 83-84.

5. Airgram - A-857, Department of State, October 20, 1971, p. 2. See also OECD, 1972, p. 85.

6. *Ibid.*, p. 2.

7. We still do not know when Petrochemicals will be decontrolled. Computer information from: European Scientific Notes, ESN-28-7, ONR, London, July 31, 1974, p. 249.

8. See Boston Consulting Group, "Japan's Technology: Gap or Lag?"

9. National Research Council, *The Computer Industry in Japan and its Meaning for the United States*, Washington, D.C., 1973, p. 16.

10. Tsurumi thesis, pp. 214-223.

11. By absorptive R&D he meant R&D devoted to absorb foreign technology. By renovative R&D he meant that portion of R&D related to foreign technologies, but devoted to new and even patentable products and processes.

12. Tsurumi thesis, p. 216.

13. *Ibid.*, p. 218.

14. *Ibid.*, p. 234.

15. *Ibid.*, 256.

16. *Ibid.*, pp. 259-260.

17. *Ibid.*, p. 262.

18. Boston Consulting Group Report: "Japan's Technology: Gap or Lag?" makes this point.

19. See p. 53 of the "Summary Fiscal Year 1972 White Paper on Science and Technology."

20. *R&D in Japan, 1973*, pp. 150-155.

21. In fact, as we will see when we talk about technology export below, these firms exported more new technology than they imported in 1972. Receipts for new cases of technology export were 18.2 billion yen.

22. John E. Tilton, *International Diffusion of Technology: The Case of Semi-conductors*. The Brookings Institution, Washington, D.C., 1971, p. 148.

23. Tsurumi found significant market restrictions in the early 1960's, so this may not be new, just increasingly onerous. See Tsurumi Thesis, p. 285-290.

24. Ozawa, *Japan's Technological Challenge to the West, 1950-1974*, p. 124-125. The data covers 1357 out of the 1546 Type A agreements in 1971.

25. Private conversation.

26. Tilton, *op. cit.*

27. Tilton, *op. cit.*, p. 147. Texas Instruments had to enter a "fifty-fifty" venture with Sony in 1968, but gained 100% control early in 1972.

28. This is one conclusion of G. R. Hall and R. E. Johnson, *Transfers of U.S. Aerospace Technology to Japan*, The Rand Corporation, July 1968, p. 77.

29. Boston Consulting Group, *op. cit.*, p. 1.

30. Tsurumi Thesis, pp. 256-258.

31. OECD, 1967, pp. 115-117.

32. It is not clear how much of this information is made public, since it is proprietary, but the Japanese seem to make a good deal more information public, for instance with regard to terms of licensing agreements, than is common in this country.

33. Private communication.

34. Memorandum, 12 December 1972, A. L. Powell, ONR, Boston, Memorandum addressed to Deputy and Assistant Chief of Naval Research (Code 101), p. 3 (on widespread use of U.S. and European consultants), and p. 7.

G. JAPANESE R&D CAPABILITIES -- STATISTICAL OVERVIEW

In the last section the role of foreign technology in Japan was surveyed. In recent years the Japanese have called for increased efforts to develop their own R&D capabilities in the face of the increased costs of foreign technology in order to become a leader in so-called "knowledge intensive" industries. What is the present status of Japanese capabilities?

1. Technology Export

First, how successful have the Japanese been in developing exportable technologies? In Table 18 we present Bank of Japan data through fiscal 1971 on receipts and payments for technology. This indicates that Japan has been increasingly able to export technologies, though exports still are but a small percentage of imports. As Table 19 indicates, Japan still has a far different technology import-export profile than the U.S. or West European countries. It is interesting to note that West Germany comes closest to Japan's profile.

In Table 20 we present the U.S.-Japan balance of payments figures in royalties and fees. These again indicate that Japanese industry has not been successful in exporting technologies back to the U.S.

There are several dangers in these statistics. First, the payments for imports include many cases that are long term for which the technology has long since been transferred. Thus they can mislead us as to the present situation. Also, the international comparison is difficult because of different ways of keeping statistics in different countries. For a discussion of how close the U.S. figures come to measuring technology transfer, see U.S. Department of Commerce, *Survey of Current Business*, December 1973, p. 14-18.

Finally, there may be differences in the attitudes of different countries to exporting and importing technology. An interesting example is one Department of State Airgram, A-857, October 20, 1971. It states that "in February 1971, the (Japanese) press reported that a request by Deering-Millikan for a technical tie-up with the Industrial and Technical Synthetic Textile Laboratory (a MITI affiliate) for the use in the U.S. of newly developed electronic auto-printing knitting machine was turned down on the grounds that the extensive use of this

Table 18

RECEIPTS AND PAYMENTS FOR TECHNOLOGY: JAPAN

Receipts		Payments		Ratio Receipts/ Payments	Year
Million Yen	$ Million	Million Yen	$ Million		
6,120	17	60,120	167	0.102	1965
6,840	19	69,120	192	0.099	1966
9,720	27	86,040	239	0.113	1967
12,240	34	113,040	314	0.108	1968
16,560	46	132,040	368	0.125	1969
21,240	59	155,880	433	0.136	1970
20,763	60	168,140	488	0.124	1971
106,778	286	1,097,505	3,069	0.097	1950-1971

SOURCE: *Technocrat*, January 1974, p. 98. By permission of Fuji Marketing Research Co., Ltd.

Table 19

INTERNATIONAL PAYMENTS AND RECEIPTS FOR TECHNOLOGY
(In $ million)

	U.S.			West Germany			U.K.			France		
Year	Rec	Pay	R/P	Rec	Pay	R/P	Rec	Pay	R/P	Rec	Pay	R/P
1969	1,894	221	8.57	96.5	251.3	.38	207.1	212.4	.98	192.8	304.8	.63
1970	2,203	225	9.79	118.6	307.1	.39	263.5	239.3	1.10	214.4	349.9	.61
1971	2,491	241	10.34	141.5	358.5	.40	--	--	--	--	--	--
1972	2,760	276	10.0	--	--	--	--	--	--	--	--	--

SOURCES: *Technocrat*, January 1974, p. 98; U.S. Department of Commerce, *Survey of Current Business*, December 1973, p. 14.

Table 20

U.S.-JAPAN BALANCE OF PAYMENTS FOR PATENTS, MANUFACTURING RIGHTS, LICENSES, ETC., 1960-1971 (MILLION $)

Year	U.S. Receipts		Payments	Balance
1960	48	(7)	--	48
1961	52	(11)	--	52
1962	53	(14)	2	51
1963	58	(15)	1	57
1964	66	(17)	1	65
1965	66	(20)	1	65
1966	70	(26)	3	67
1967	97	(33)	4	94
1968	133	(41)	4	129
1969	157	(51)	4	153
1970	202	(66)	4	198
1971	225	(80)	5	220
1972	245	(101)	?	?

SOURCES: National Science Board, *Science Indicators, 1972*, U.S. Commerce Department, *Survey of Current Business*, December 1973, p. 106.

These figures are from the *Survey of Current Business*, and include only unaffiliated receipts and payments. Direct investment related transactions in royalties and fees are not included. These totaled $80 million in 1971, or about 25% of total U.S. receipts from Japan of $305 million. Presumably direct investment related payments to Japan would be small for the period. Figures in parentheses are for direct-investment related transactions in royalties and fees. It might be a fairer indicator to add these receipts to the balance column.

technology in the U.S. might hurt Japanese textile exports."[1] One could quote many similar examples on the U.S. side, and perhaps these cases of reluctance to export average out. What may not average out is the desire to import. The Japanese are far more diligent in seeking out foreign technologies than their U.S. or European counterparts. The so-called not-invented-here syndrome is reputed to be stronger in the West, and there is perhaps a greater complacency in the U.S. about staying informed on foreign developments.

We do have statistics for the year 1972 on exports of technology by most businesses in Japan. These statistics show that 650 companies out of 9,705 in the sample had exported technology. These 650 companies had more than a quarter of the operating profits of all 9,705 companies (1,939 billion yen out of 7,499 billion yen), and performed more than half of all R&D in the industrial sector (555 billion yen out of 1045 billion yen). Thus we are clearly dealing here with the large companies, and these companies are well covered by the Japanese statistics. A total of 1760 new programs of technology export and 1,076 continued programs were reported. The new programs earned 18,206 million yen (about $60 million) and the continued programs 23,967 million yen (about $80 million).[2]

Also, somewhat surprisingly, in the non-electrical machinery and communications and electronics equipment industries most of the new cases of technology export in 1972 involved Japanese firms capitalized at less than 100 million yen. Only 19 of 932 cases in non-electrical machinery (worth 627 million out of 2,051 million yen) and 30 of 483 cases in electronics and communication equipment (worth 256 million out of 4,185 million yen) involved Japanese firms capitalized at more than 100 million yen. This may be a reflection of the structure of these sectors. It could also be that large companies set up small subsidiaries in these sectors for the purpose of exporting technology. One would have expected the major exporters in the electronics sectors to be NEC, Toshiba, Fujitsu, Hitachi, Sony, Matsushita, etc., certainly all capitalized at far more than 100 million yen.

Aside from these sectors, the Japanese statistics do show that most of the technology export does involve companies capitalized at more than 100 million yen.

Southeast Asia is the major recipient of Japanese technology. As Table 21 indicates, Southeast Asia was involved in 46% of the export cases and paid 48% of the royalties to Japanese industries. North America was involved in 17% of these cases, paid 15% of royalties; Europe was involved in 23% of the cases, paid 24% of royalties. South America had 7% of both cases and royalties. One should recall, however, that the total value being considered is only $110 million, and that North America is paying only $16 million, while receiving $560 million (168 million yen) from the Japanese companies capitalized at more than 100 million yen.

About 40% of all technology exports by Japan are in the area of industrial chemicals,[3] and other important areas include electronics and communications equipment (13%), iron and steel (11%), non-electrical machinery (7%), and transport machinery (5.5%). These, as we have seen, are also the sectors where the greatest amount of funding is devoted to R&D.

The point of this statistical analysis is that the backflow of technology to the U.S. and Europe has been quite small. There have been several well-publicized examples, such as the Honda stratified charge engine to Ford and Chrysler and the Mazda rotary engine to GM, but they have been relatively rare.

2. Patent Activity

Another indicator we may use is the patent data in the U.S. and Japan. The U.S. Patent Office has recently begun a series of reports on technology assessment and forecast, which include extensive data on foreign shares of U.S. patents granted. Figure 6 shows the rapid change in the Japanese share, increasing from 1% to almost 7% in a 10-year period, and showing an especially sharp increase in the last few years.

Similarly, in West Germany Japan has increased its share of patents granted from 3.56% in 1967 to 9.72% in 1971.[4]

There are difficulties in using patent data that should not be ignored. First of all, the large majority of patents are never

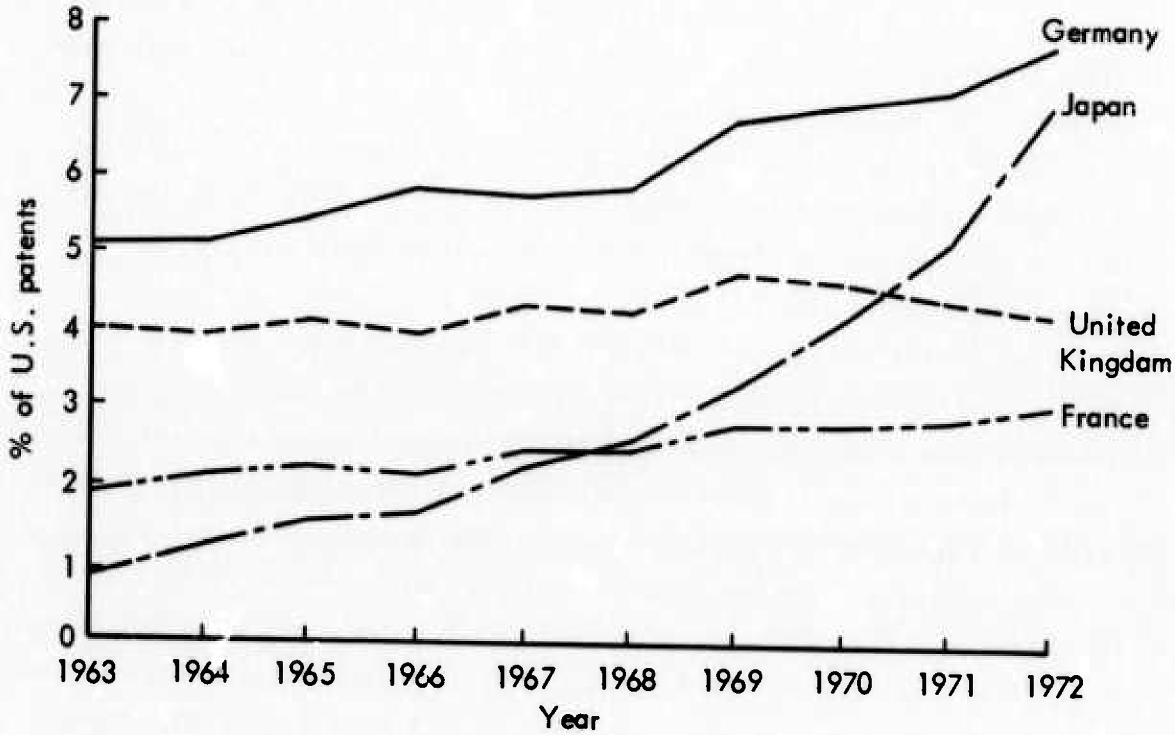
Table 21

TECHNOLOGY EXPORT BY COMPANIES WITH 100 MILLION YEN OR MORE OF CAPITAL (1972)

Country	Number of New Cases	%	Number of Continued Cases	%	Total Number	%	Receipts for Technology Export (Million Yen)					
							New Cases	%	Continued Cases	%	Total	%
Southeast Asia	87	29.9	405	51.8	492	45.9	5,213	42.5	10,118	50.7	15,331	47.6
North America	71	24.4	114	14.6	185	17.2	2,475	20.2	2,339	11.7	4,814	14.9
Europe	99	34.0	144	18.4	243	22.6	3,448	28.0	4,375	21.9	7,823	24.3
South America	16	5.5	54	6.9	70	6.5	476	3.9	1,708	8.6	2,184	6.8
TOTAL	291	100.0	782	100.0	1,073	100.0	12,277	100.0	19,962	100.0	32,239	100.0

SOURCE: *R&D in Japan, 1973*, p. 154-155.

NOTE: Difference between total figures and sum of figures shown in four geographic areas reflects exports to other world regions.



Saurce: Technalogy Assessment and Farecast, December 1973, U.S. Department of Cammerce, U.S. Patent Office.

Fig.6—Annual fareign share af U.S. patents—selected countries

commercialized. There is normally a delay of several years between application for a patent and its award. There are differences between nations in the rigor of tests for originality, and differences between nations in the relative success of litigation involving patent rights. There are differences between industries on the value of patenting discoveries, although for the industries we consider this factor is probably not important.

In spite of these difficulties the patent data does give useful indications of Japan's growing overall R&D capabilities and does help to point to areas of special importance.

Table 22 indicates that the Japanese have been able to maintain a constant share of patents registered in Japan. This is in contrast to the U.S., where the foreign share of U.S. patents has increased from 17% in 1963 to 31% in 1972.

The patent balance between the U.S. and Japan has now been all but eliminated (Table 23). If we had the 1972 figures they would probably show a balance of only a couple hundred patents on the U.S. side. However, the U.S. percentage share of Japanese patents would still be more than twice the Japanese share of U.S. patents.

In Appendix 1 the profile of Japanese patent activity in the U.S. is presented, together with a comparison with overall patent activity, taken from the June 1974 U.S. Patent Office report. These figures cover U.S. patent activity in the three-year period ending June 30, 1973, a period during which Japan received about 5% of all U.S. patents.

One notices if one scans Appendix 1 the selectivity of the Japanese efforts. Table 24 lists the classes in which the Japanese obtained more than 10% of U.S. patents during the three-year period. The greatest activity is concentrated in a few general areas: fermentation, chemistry, photography, consumer electronics (sound systems, TV, tuners), optics, metallurgy, horology, automotive technology, textiles, and other electrical systems. Anyone familiar with the structure of Japanese industry will not be surprised at this list of areas. This is a first indication that the Japanese have developed their own technologies in recent years, often based on their experience with previously imported technologies. In many of these areas and

Table 22

NUMBER OF FOREIGN AND DOMESTIC PATENTS REGISTERED IN JAPAN

Country	1967	1968	1969	1970	1971
U.S.	3,432	4,903	4,657	4,774	5,700
West Germany	1,133	1,531	1,385	1,572	2,197
U.K.	611	777	720	772	920
Switzerland	518	540	474	610	722
France	386	473	413	506	620
Total foreign	6,896	9,396	8,870	9,475	11,652
Domestic	13,877	18,576	18,787	21,403	24,795
Total	20,773	27,972	27,657	30,878	36,447
Foreign total (%)	33.2	33.6	32.1	30.7	32.0
U.S. total (%)	16.5	17.5	16.8	15.4	15.6

SOURCE: *Industrial Property*, December issues, 1968-72. Monthly review of the World Intellectual Property Organization (WIPO) and the United International Bureau for the Protection of Intellectual Property (BIRPI), Geneva.

Table 23

U.S.-JAPAN PATENT BALANCE

Year	Awarded to U.S. in Japan	Awarded to Japan in U.S.	Balance
1967	3432 (16.5)[a]	1424 (2.17)	2008
1968	4903 (17.5)	1464 (2.48)	3439
1969	4657 (16.8)	2152 (3.19)	2505
1970	4774 (15.4)	2625 (4.07)	2149
1971	5700 (15.6)	4033 (5.15)	1667

SOURCE: *Industrial Property*, December issues, 1968-72.

NOTE: In 1972 the gap may have all but disappeared. We know Japan got 6.85% of U.S. patents in 1972, as opposed to 5.15% in 1971. This probably means the absolute number for Japan was greater than 5,000.

[a]Percent of total grants in parentheses.

Table 24

PERCENTAGE OF U.S. PATENTS OBTAINED BY
JAPANESE NATIONALS, JUNE 1970-JUNE 1973
(by U.S. patent class)

Patent Class	Percent	Title
28	11.2	Textiles, manufacturing
58	17.5	Horology
84	19.6	Music
95	22.3	Photography (except lenses)
96	14.8	Photographic chemistry, processes and materials
123	11.0	Internal combustion engines
148	11.4	Metal treatment
178	10.1	Telegraphy (includes TV)
179	10.9	Telephony
195	23.1	Fermentation chemistry
274	25.9	Sound recording & reproducing
303	10.0	Fluid pressure brake and analogue systems
313	12.2	Electric lamp and discharge devices
315	11.2	Electric lamp and discharge devices, systems
322	12.7	Electricity, single generator systems
334	14.7	Tuners
338	14.0	Electrical resistors
352	13.5	Optics, motion pictures
355	14.7	Photocopying

SOURCE: *Technology Assessment and Forecast*, June, 1974,
U.S. Patent Office.

subareas, e.g., fermentation chemistry, photography, consumer electronics, magnetism, piezoelectricity, and electron microscopy, the Japanese have been making original contributions for much of the post-war period, and in some cases earlier. In others, such as automotive technology and communications, the Japanese contributions have been of more recent vintage. In the next section we will outline several areas of science and technology, pointing to Japanese achievements and setbacks, with attention on the present and future.

JAPANESE R&D CAPABILITIES

Footnotes

1. Department of State Airgram, A-857, October 20, 1971.

2. The 42 billion yen total seems rather high when compared with the figures for 1971 in Table 18, more than doubling in a year. The STA and the Bureau of Statistics may be using different definitions for technology export. All figures are from *R&D in Japan*, 1973, Tables 14 and 16, p. 150·151, 154-155.

3. It is the industrial chemical sector that is most successful. 15.3 billion yen out of total receipts of 42.2 billion yen in 1973 went to this sector. It may say something about its strength. Payments were 30.3 billion yen, with 29.1 billion yen in continued cases, 1.2 billion yen in new cases. 10.2 billion yen of receipts came from Southeast Asia.

4. December 1968 and December 1972 issues of *Industrial Property*, Monthly Review of the World Intellectual Property Organization (WIPO), Geneva.

III. PRESENT STATUS OF SCIENCE AND TECHNOLOGY IN JAPAN

A. INTRODUCTION

Although this part of the report surveys a wide area of Japanese science and technology, it does not aim at being comprehensive. That is beyond the scope of this report. Instead, we aim at developing a body of information from which trends may be detected. The fact that we do not cover an area should not be interpreted as meaning Japanese capabilities are limited in that area.

We have chosen to organize the material by industrial sector. This has allowed us to make some use of Japanese statistical data. This means however that some fields of science are mentioned in several sections. For instance, laser technology is mentioned in connection with applications to optical communications and to nuclear fusion.

We have used a variety of indicators of strength: the personal evaluation of experts, either from the literature or from private conversations, the success in obtaining patents in the U.S., the length of time taken to imitate breakthroughs, the extent of cross-licensing, the extent and type of technology import, the extent of joint international research efforts, and the ability to export technology. Our approach has been descriptive, rather than analytical. We have not been able to use all of these indicators in any one section. (A possible future study might deal with the development of the analytical tools needed to better quantify what we mean by relative strengths and weaknesses.)

For the different areas covered we have also tried to mention, when available, the level of effort in terms of manpower and funding, and in comparison with U.S. levels, and some historical background on the same area.

B. IRON AND STEEL

Since the beginning of the modern era, the steel industry has played a major role in the Japanese economy, and has received a great deal of government attention, perhaps more in relation to capacity than in relation to technology. Japan's crude steel production reached 96.9 million metric tons in 1972, placing Japan a close third in world crude steel production. Various Japanese steel companies operate most of the largest blast furnaces in the world, many with capacities well in excess of 5,000 cubic meters. Nippon Kokan's Fukuyama Works is the world's largest integrated steelworks, a showplace for the Japanese industry.

The steel industry in 1972 employed 2.9% of all researchers in the industrial sector, and spent 4.0% of all research funds.[1] Expenditures per researchers of 11,490,000 yen ($38,000) were among the highest of any industry.

The relative share of the steel industry in industrial R&D has declined since 1961, when 3.8% of all researchers worked in this sector and 6.1% of all R&D expenditures took place in this sector.

Research is concentrated in the largest steel firms. The five largest firms spent an average of $21 million each on R&D in 1972. This was 75.6% of the industry's expenditures. They also employed 69% of the industry's researchers. Expenditures on R&D were only .92% of sales for these firms. Nippon Steel by itself employs 30% of the researchers in the industry. In 1973 its expenditures on R&D grew to $68 million, 1.1% of its sales.

Most of the work performed in industrial steel labs is developmental. In 1972 development consumed 62% of expenditures, applied research 29%, and basic research only 9%. The specialties of the 3,600 research workers in the industrial sector included mining and metallurgy (1409), mechanical engineering (704), chemistry (668), and mathematics and physics (357).

Approximately six percent of R&D in the steel sector went to research on pollution control in 1972. The most important areas of R&D are the development of new steel alloys, the development of new processes for handling steel, and improvement of present processes.

The industrial effort is supported by research at the research institutions and the universities. There are 589 researchers in research institutions with mining and metallurgy as their specialty, and 1316 researchers in the university sector with this specialty. Work in these institutions is more oriented to basic research, and in the area of magnetic alloys, is among the best in the world. In the university sector the most famous institution is The Research Institute for Iron, Steel, and Other Metals at Tohoku University in Sendai. It was here that Honda, the inventor of the KS magnet in 1917, and Mishima, who developed the MK magnet in 1931, worked. Their work paved the way for the development of the Alnico magnet, still one of the most important hard magnetic alloys. Today Professor Masumoto is a world leader in the development of amorphous alloys. The University of Tokyo is also an important research center in this field. Professor Kondo is well known for his study of the low temperature properties of dilute magnetic alloys.

The Japanese steel industry has traditionally relied on foreign technology. After the war the LD (Linz-Donawitz) pure oxygen steel process was introduced from Austria. Today it is virtually the sole method used in making carbon steels in Japan. The Japanese did improve the furnace developing better lining refractories, the multinozzle oxygen lance and new methods for recovering waste gases, all of which enhanced the economic advantages of the system.[2]

Another example of technology import during this period was the licensing of free standing blast furnace technology by Kawasaki from Wolf Co. of West Germany.[3] This was used for Chiba No. 1 and No. 2 blast furnaces. Today free-standing and semi-free-standing blast furnaces are in increasing use in Japan, as Nippon Steel has also adopted this construction.

During the period 1950-1964 there were 99 type A agreements and 242 type B agreements for licensing foreign technology in this sector, and this licensing has continued (see Table 14 above, where all metals are grouped together).[4] By the late 1960's domestic R&D had made significant strides, and Yawata Steel was widely publicized as exporting more technology than it imported. This included jumbo

blast furnace design technology, sold to Ashmore, Benson, Pease and Co., Britain's biggest blast furnace builder, and assistance in modernizing a flat steel production facility in Bremen of Kloeckner Werke A. G., Duisberg.[5] Moreover, by 1965 Japanese blast furnaces consumed only 507 kilograms of coke to produce a metric ton of pig iron, the lowest coke ratio in the world.[6]

Still there was extensive use of foreign technology. Guillain outlined a partial list of Mitsubishi Heavy Industries (MHI) licensing agreements in effect in 1968:

> High-pressure blast furnaces and sintering processes (preliminary treatment of ore) - McKee and Co., U.S.
>
> Pure oxygen L.D. convertors and Kaldo converters - Pentsel Bamag A.G., West Germany.
>
> Continuous casting plants - Loftus Engineering, U.S.; Earle Olsson, Sweden.
>
> Rolling Mills - Mesta Machine Co., U.S.; Schoemann, A.G., West Germany; Loftus, U.S.; Drever Co., U.S.
>
> Machine Tools - Innocenti-Berthiez, Italy; Oerlikon, Switzerland; Rockford, U.S., Acme and Gridley, U.S.; Caterpillar, U.S.[7]

MHI was the biggest producer of iron- and steel-working plant and machinery at that time.

Japan has not exported any significant steel technology to the U.S. In 1972, of the 92 cases of steel technology export involving companies capitalized at more than 100 million yen, the U.S. was involved in 8, and the payments were negligible. Most of Japan's exports of steel technology were to Southeast Asia, South America, and Europe (with which Japan had a positive balance of payments for steel technology). Of the 251 cases of technology import, 131 involved North America and 120 Europe. Payments for technology totaled 5,145 million yen ($17 million) and receipts totaled 4,294 million yen ($14 million).

In several U.S. patent classes related to metals and metallurgy the Japanese have significant activity. These include the following classes: 72 (metal deforming - 6.2%), 75 (metallurgy - 8.9%), 148 (metal treatment - 11.4%), 228 (metal fusion bonding apparatus - 5.3%), and 266 (metallurgical apparatus - 6.7%).[8] The percentages are for the 3 year period ending June 30, 1973.

Current developments that give some indication of present capabilities include the following cases. Kawasaki's Chiba Iron Works is presently capable of manufacturing the largest outside diameter steel pipes in the world. The outside diameter of the product ranges from 508 to 1,422 mm at present, and will be extended to 1,652 mm (64 inches) in the future.[9] The UOE pipe mill has an annual capacity of 300,000 tons.

Kobe Steel, Ltd. has developed the world's first practical double-acting indirect extrusion machine, with a capacity of 3,600 tons. It can extrude aluminum alloy blank at a speed of up to 90 mm/minute. With increased demand for the production of aluminum alloy shapes, this may be an important development.[10]

Yutaka Kosakusho Co. and the Department of Precision Engineering, Osaka University, have jointly developed a new pipe bending process based on the exertion of force on the interior surface. Again due to increased demand for pipes bent to fine tolerances by aircraft, chemical, and shipbuilding industries, this may be an important development. In any case, it is an example of the industry-university cooperation. Apparently the firm put forward the idea and the university demonstrated the theoretical basis of the process and made experiments on it.[11]

Finally, in the area of steel alloys Japanese work is outstanding, as it has been since the days of Honda. Work on soft magnetic alloys such as Si-Fe and Ni-Fe alloys, is extensive and at world levels.[12] An example is the high permeability grain-oriented silicon steel ORIENTCORE HI-B developed by Nippon Steel, which is used as the core material of large transformers and large rotating machines.[13] This technology has been licensed abroad by Nippon Steel. The situation is similar for hard magnetic alloys, such as the RCo_5 (cobalt rare earth) alloys.[14]

A recent major development has taken place at the Institute for Iron, Steel, and Other Metals at Tohoku University. There Professor Masumoto and Assistant Professor Hashimoto have developed an amorphous steel alloy in solid form using a "centrifugal quenching process." This alloy contains iron, phosphorus (8%), carbon (2%), and several percent of chromium. It is several times as tough as stainless steel

and resistant to corrosion and pitting even in a dilute solution of hydrochloric acid. This alloy can be mass-produced and may have significant applications for areas with high strength requirements and as a coating material where anti-corrosion is important, e.g., in nuclear and chemical plants.[15]

Table 25

IRON AND STEEL R&D STATISTICS

Year	Number of Researchers	Expenditures on R&D (Million Yen)	Expenditures Per Researcher (10,000 Yen)	Expenditures As Percent of Sales
1961	1760 (3.8)	9954 (6.1)	566	.52
1964	2185 (3.7)	13323 (5.5)	610	.65
1967	2736 (3.4)	19858 (5.2)	726	.63
1969	3111 (3.3)	30268 (4.8)	973	.63
1970	3361 (3.0)	36565 (4.4)	1088	.64
1971	3767 (3.3)	40881 (4.6)	1085	.77
1972	3600 (2.9)	41379 (4.0)	1149	.77

Numbers in parentheses are percentages of all industrial researchers and expenditures that steel constitutes.

SOURCE: *R&D in Japan, 1973.*

Major Companies

1. Nippon Steel (Yawata-Fuji merger)
2. Nippon Kokan
3. Sumitomo Metal
4. Kawasaki Steel
5. Kobe Steel

IRON AND STEEL

Footnotes

1. Statistics here and below from *R&D in Japan*, 1973.

2. Statement of Dr. K. Kaneshige before Committee on Science and Astronautics, U.S. House of Representatives, January 24, 1967. P. 39, Panel on Science and Technology, Eighth Meeting, U.S. Government Printing Office, 1967.

3. *Technocrat*, "Adoption of Self-Standing Structure for Large-Capacity Blast Furnaces," April 1974, p. 6.

4. Tsurumi Thesis, p. 205-208.

5. "Japan: Now the Imitator Shows the Way," *Business Week*, May 16, 1970, p. 92.

6. Kaneshige, *op. cit.*, p. 38.

7. Guillain, R., *The Japanese Challenge*, p. 129.

8. Technology Assessment and Forecast, June 1974, U.S. Patent Office.

9. *Technocrat*, "Completion of Large Diameter Steel Pipe Manufacturing Process," May 1974, p. 11.

10. *Technocrat*, "World's First Double-Acting Extrusion Machine," January 1974, p. 7.

11. *Technocrat*, "Development of a New Pipe Bending Process," June 1974, p. 6.

12. For a review of Japanese work on soft magnetic alloys, see: "Recent Developments on Soft Magnetic Alloys in Japan," K. Narita, *IEEE Transactions on Magnetics*, Vol. MAG-10, No. 2, June 1974, p. 104.

13. "The Transformer Characteristics of 'Orientcore HI-B'," T. Suzuki, et al, *IEEE Transactions on Magnetics*, Vol. MAG-8. No. 3, September 1972, p. 321.

14. Opinion of Professor F. Humphrey, Cal Tech, based on attendance of 1972 Intermag Conference in Japan, of which he was co-chairman.

15. "New Metal Amorphous Alloy," *Technocrat*, June 1974, p. 6 and "Super-Steel Alloy Resists Rust Better Than Stainless," *Japan Report*, June 1, 1974, p. 8.

C. NON-FERROUS METALS

The non-ferrous metals sector has been very largely dependent on foreign technology. A look at the level of effort in the sector helps to explain why. Only 1.5% of all researchers were employed in this sector in 1972. Only 1.8% of expenditures were in this sector, and expenditures have averaged about 1% of sales (although this is not very different from the U.S. figure). Almost all the R&D goes to development (68%), with applied research (27%) and basic research (5%) receiving much smaller shares.[1]

Total expenditures for R&D in this sector in 1972 were 18,866 million yen (or $63 million). Only 2% of this went for work on pollution control. Over one third (665) of the 1,856 researchers in this sector were chemists. Other important fields of specialty were mining and metallurgy (406), electrical engineering and telecommunications (392) and mechanical, marine, and aircraft engineering (233).

In this sector it is again the few giant firms that perform most of the R&D. The six firms capitalized at more than 10 billion yen performed 46% of R&D in 1972.

During the period 1950-1964 Tsurumi found that there had been 73 type A licensing agreements and 55 type B licensing agreements concluded in this sector.[2]

The OECD in a study in the late 1960's found that there had been little innovation in this sector in Japan.[3] Most technology had been licensed or imitated from abroad. One development in the copper sector was found worthy of note, the oxygen smelting (Momoda) process.

In 1972 there were only 43 cases of technology export worth 309 million yen. These exports were almost all to Southeast Asia and South America. There were 159 cases of import of technology worth 2,604 million yen, 69% of this going to North America.

Only in this last year have there begun to be signs of significant Japanese export of technology in this sector. One agreement involves Revere Copper and Brass Inc. of the U.S., which is purchasing Sumitomo Chemical Co's aluminum refining technology for use in a joint venture plant in Scottsboro, Alabama.[4]

Mitsubishi Metal is also said to have several potential purchasers of its "continuous copper-producing" technology. This technology is said to have a variety of advantages, including a smelting speed 3-6 times faster than conventional methods, high heat efficiency, low energy consumption, low waste gas production, and lower construction and operation costs.[5]

These developments, both reported during 1974, are certainly among the first major sales of Japanese technology in this sector.

Table 26

NON-FERROUS METALS R&D STATISTICS

Year	Number of Researchers	Expenditures on R&D (Million Yen)	Expenditures Per Researcher (10,000 Yen)	Expenditures as Percent of Sales
1961	1478 (3.2)	6365 (3.9)	431	.83
1964	1664 (2.8)	7863 (3.2)	473	1.10
1967	2306 (2.8)	11149 (2.9)	483	.89
1969	1597 (1.7)	13689 (2.2)	857	.80
1970	1900 (1.7)	17872 (2.2)	941	.93
1971	2050 (1.8)	17084 (1.9)	833	1.04
1972	1856 (1.5)	18866 (1.8)	1016	.99

SOURCE: *R&D in Japan, 1973.*

NOTES: Number in parentheses are percentages of all industrial researchers and total industrial expenditures. Principal companies:

Aluminum: Nippon Light Metals (35% owned by Alcan); Showa Denko KK.
Copper : Nippon Mining Co., Mitsubishi Metal Mining Co.
Titanium: Toho Titanium Co., Osaka Titanium Co.
Nickel: Sumitomo Metal Mining Co., Taiheiyo Nickel Co., Nippon Mining Co.

NON-FERROUS METALS

Footnotes

1. Statistics here and below taken from *R&D in Japan*, 1973.

2. Tsurumi Thesis, p. 205-208.

3. *Gaps in Technology: Non-Ferrous Metals*, OECD, Paris, 1969.

4. *Japan Economic Journal*, "Revere Will get Sumitomo's Technology," July 9, 1974.

5. *Japan Economic Journal*, "Mitsubishi Metal is Slated to Export Copper Technology," July 9, 1974.

D. THE CHEMICAL INDUSTRY

Like the steel industry, the chemical industry has long been emphasized in Japan. Most major innovations have been introduced from abroad, but there have also been major domestic innovations in such areas as nylon 6, urea fertilizer, carbon fiber, and amino acids. This is the industry most able to export its technology abroad, even to advanced nations.

Due to the size of the industry, we have chosen to present a statistical overview of the industry as a whole, followed by a discussion of a few selected areas where either foreign technology has played a large role, or the Japanese have developed significant capabilities, or, more usually, both.

1. Statistical Overview

The chemical sector makes up about one-fifth of all industrial R&D in terms of both expenditures and manpower. There has been a downward trend in the share of industrial chemicals (from 15% of expenditures in 1961 to 9% in 1972), but the rest of the chemical sector has maintained or increased its share of industrial R&D over this period.[1]

It is also an industry that is relatively R&D intensive, as measured by expenditures on R&D as a percentage of sales, with 2.34% of sales going to R&D in 1972. This is still significantly below the U.S. figure of about 3.9% in 1971.

In scale also the Japanese chemical industry's R&D effort is dwarfed by that of their U.S. and European counterparts. In FY 1972 the five largest firms in the chemical sector spent 36.7 billion yen ($122 million) on R&D. The 20 largest firms spent $289 million. This compares to Dupont's expenditures of $256 million in 1972, and $276 million in 1973.

R&D is also surprisingly decentralized in the chemical sector. The seventeen firms capitalized at more than 10 billion yen utilize only one-third of all R&D expenditures and employ only one-quarter of the researchers in the sector. Fourteen of the seventeen largest firms are in the industrial chemical subsector; one is in the drug

subsector, one in the oils and paints subsector, and one in the "other chemicals" subsector.

Overall 15% of industrial R&D in this sector goes to basic research (27% of the expenditure in the pharmaceutical sector goes to basic research, only 8% for oils and paints). Twenty-seven percent of industrial R&D goes to applied research, and 58% to development.

In addition to industrial efforts, there were 7,893 chemists in the university sector and 3,599 chemists in the research institution sector in 1972. We will below see several examples of significant work performed in the universities.

The industry has been largely dependent on the introduction of foreign technology throughout the modern era. Table 27 shows the time lag in the first commercialization of various important chemical products. The Japanese have had to license or imitate all of these developments (although in the case of nylon 6, Toyo Rayon did independently develop its own nylon 6 in the late 1930's, but after the war had to take out a license because of the patent position of Dupont).

During the period 1950-1964 there were 308 type A licensing agreements and 166 type B licensing agreements concluded by the Japanese chemical industry.[2] This trend continued during the 1960's (see Table 14 above) with the chemical sector concluding about 20% of all licensing agreements between 1965 and 1970.

In 1972 the chemical sector was involved in 99 new technology imports and 780 continued programs, costing 1600 million yen and 39,500 million yen, respectively. More than 80% of these payments were going to the U.S., but largely for technologies that had already been transferred, for instance, for basic petrochemical technologies introduced to Japan over the past 20 years. The chemical industry was able to export technology to the U.S. and, in fact, receipts for new exports of technology to the U.S. (1,259 million yen) exceeded those for new imports (876 million yen), although only 1,030 million yen was received from the U.S. for continued cases, and 32,576 million yen was paid to the U.S. for continued cases. Almost all of the exports of technology were in the industrial chemical sector, and the great majority of cases involved Southeast Asian countries.

Table 27

TIME LAG IN COMMERCIALIZATION OF MAIN CHEMICAL PRODUCTS

Product	First Year for Commer-cialization	U.S.	U.K.	France	West Germany	Italy	Japan
Celluloid	1870	0	7	5	8	54	38
Phenol	1909	0	7	10	1	13	14
Cellophane	1917	7	13	0	8	29	12
Alkyd resin	1926	0	3	2	1	1	5
Urea resin	1928	1	0	2	1	8	7
Polyvinyl alcohol	1928	0	21	9	0	26	8
Polystyrene	1930	3	20	21	0	12	27
M M A	1931	6	3	8	0	7	8
P V C	1937	2	9	9	0	20	18
L D P E	1938	4	0	17	7	15	21
Melamine	1940	1	8	17	0	13	13
Vinylidene chloride	1941	0	-	21	-	-	10
Nylon	1941	0	9	2	2	5	9
Polyester	1942	0	8	8	11	7	11
Fluorine resin	1943	0	2	15	15	12	12
ABS resin	1946	0	10	14	9	-	17
Epoxide resin	1947	0	8	-	8	11	15
Acetal resin	1953	0					
Polypropylene	1957	0	2	3	-	0	6
Polycarbonate	1957	0			0		2

SOURCE: *Technocrat*, January 1974, p. 83. By permission of Fuji Marketing Research Co., Ltd.

Total receipts for export of technology in the chemical sector in 1972 were 16,409 million yen ($55 million). This was 39% of all receipts reported by the Bureau of Statistics, a share twice the size of the chemical sector's share of R&D funds. Also, receipts for new technology transfer cases with Europe exceeded payments (1,500 million yen vs. 666 million yen), but payments exceeded receipts for continued cases (6,230 million yen vs. 1,642 million yen).

We will below discuss some of the cases of technology transfer in this sector, and point out at least a few areas of Japanese strength. As we will see, there are extensive ties to western firms in many subsectors. There is also widespread use of American and European consultants and short-term employment of foreign industrial chemists and engineers.

The Soviet Union has provided almost no technology in this sector, although recently Toyo Engineering has imported two Soviet techniques, one for concentrating solutions by using thin rotary films for rapid evaporation, and the other an incinerator for industrial waste liquids.[3]

In several classes of U.S. patent statistics related to chemicals the Japanese show significant activity. Previously mentioned were fermentation chemistry and photographic chemistry (see Table 24). Table 28 presents a list of various subclasses in which Japan showed significant activity in 1972, and comparisons with U.S. and West Germany, Japan's principal rivals in the chemical sector.

Overall one gets the impression that in this sector the Japanese are at world levels almost everywhere, and now have the capability of coming up with interesting new chemicals. They lead the world in the production of such diverse products as rayon, lysine, and saccharin. In plastic and resin production they trail only the U.S. and West Germany. Several significant new developments will be mentioned below in such areas as carbon fiber and pharmaceuticals.

Table 28

NUMBER OF 1972 U.S. PATENTS OBTAINED BY CITIZENS OF U.S., GERMANY, AND JAPAN IN SELECTED CHEMICAL AREAS

	Total	United States	Germany	Japan
1. Synthetic resins admixed with a solvent (heterocyclic or sulfur compound)	148	74	26	24
2. Nitrogen-containing synthetic resin admixed with an amine or amide solvent	132	76	19	19
3. Formaldehyde polymers	31	10	11	11
4. Certain interpolymer resins	307	170	40	39
5. Certain copolymers prepared from unsaturated carboxylic acid ester monomers	193	103	21	32
6. Homopolymers of certain vinyl halides	115	46	18	21

SOURCE: *Technology Assessment and Forecast*, U.S. Patent Office, December, 1973.

Table 29

CHEMICALS R&D STATISTICS

Year	Number of Researchers	Expenditures on R&D (Million Yen)	Expenditures/ Researcher (10,000 Yen)	Expenditures as Percent of Sales
1961	9,874 (21.4)	36,832 (22.5)	373	1.64
1964	14,552 (24.7)	66,002 (27.1)	454	1.88
1967	19,075 (23.4)	91,302 (24.1)	479	1.85
1969	21,565 (22.9)	137,296 (21.9)	637	1.99
1970	24,669 (22.2)	175,132 (21.3)	710	2.10
1971	25,232 (22.4)	193,682 (21.6)	768	2.30
1972	26,207 (21.0)	199,235 (19.1)	760	2.34

SOURCE: *R&D in Japan, 1973.*

NOTE: Numbers in parentheses are percentages of all industrial researchers and total industrial expenditures.

2. Caustic Soda

This sector is worthy of note because it is presently undergoing a change in production methods. In the past mercury cell production was the method used for the production of caustic soda in Japan. This has caused severe environmental problems, including severe effects on people's health. Minimata disease has been traced to mercury in industrial wastes. The industry is under government order to convert 75% of its mercury cell facilities to the non-polluting diaphragm cell process by September 1975 and to complete the transfer by March 1978. To complete this transformation, Japanese caustic soda manufacturers are said to be seeking technical assistance from U.S. caustic soda manufacturers. Chiyoda Chemical Engineering, for example, has a licensing agreement with Hooker Chemical of the U.S. for its diaphragm-cell process.

One U.S. firm, Dow Chemical, is considering setting up a wholly owned subsidiary to produce caustic soda in Japan. The production capacity might be about 720,000 tons/year, which would be about 16% of expected demand in 1976. Dow has never licensed its diaphragm cell technology to outside firms, and its move into Japan is being strongly opposed by the industry. This is widely regarded as a test of Japanese foreign investment liberalization, as this sector was liberalized in May 1973. The feasibility study for the plant will not be completed until March 1975. This will be an interesting development to monitor, especially to see if Dow is pressured to license its diaphragm cell technology as the price of entry, as IBM and TI were in similar cases in previously liberalized days.[4]

3. Basic Petrochemicals

Basic petrochemical technology was introduced to Japan starting in 1957, with the U.S. providing most of the know-how. In particular the naphtha cracking technology was licensed from Lummus and Stone and Webster.[5]

This is an industry over which the government keeps close watch. It is felt to be a crucial industry by MITI, one still in need of protection. It is still under MITI licensing control, and foreign investment in the sector is limited.

In recent years considerable attention has been given to developing independent naphtha cracking technology. Over the past three years both Mitsubishi Petrochemical and Mitsui Petrochemical have developed their own proprietary processes for naphtha cracking. The "Mitsubishi ethylene process" has been exported to China. The Mitsui process is said to reduce nitrous oxide (NO_x) discharge to about 1/3 the level of the conventional cracker.[6]

This is also an area in which MITI sponsored a big project. This project, which lasted from 1967 until 1973 and spent approximately thirteen million dollars, had the goal of developing processing methods for olefins (ethylene, etc.) through the direct cracking of crude oil. This development was apparently unsuccessful.[7]

But Chiyoda Chemical Engineering and Kureha Chemical have signed an agreement with Union Carbide to continue the development of a process for the production of ethylene by the direct cracking of crude oil. The three companies are jointly undertaking R&D on the process, following up the work under MITI sponsorship.[8]

4. Fertilizers

After World War II fertilizer was given the top priority in the rehabilitation of the chemical industry in order to secure a sufficiency of food. This sector had been well developed before the war. The Tokoshi process for producing ammonium sulphate had been developed in Japan in 1929.[9]

By the late 1960's Mitsui Toatsu Chemicals, Inc. was collecting about $5 million annually in licenses and fees for its fertilizer technology. Its processes, used by 55 plants in 20 countries, account for one-third of total world production of urea fertilizer. U.S. clients include Borden, Fluor, and Essor Research and Engineering.[10]

5. Polymers: Fibers and Plastics

This field has long been one of significant Japanese interest. Fiber research started with cellulose (rayon) in 1913. Work on the development of synthetic fibers continued during the pre-war period and culminated in the independent development of nylon 6 by Hoshino of Toyo Rayon just prior to World War II. It is interesting to note that Mitsui Bussan Trading Co. provided Toyo Rayon with information on Dupont's nylon 66 in 1938, which helped to direct Hoshino's work.[11] After the war Toyo Rayon did have to license this patent for nylon 6 from Dupont due to Dupont's established patent position.

Since the war the Japanese have imported a great deal of plastics technology. Licenses were taken out with such firms as I.C.I. (Imperial Chemical Industries) for polyethylene and Montecatini for polypropylene. Attention was first given to PVC (polyvinyl chloride) since this could be produced from limestone by the acetylene process with a mercury catalyzer.[12] Asahi Chemical and Dow Chemical built the first polystyrene plant after entering a 50-50 joint venture in 1952. Another close relationship has been between Phillips Petroleum and Showa Denko. This began in the mid-1950's with the licensing of Phillips' high density polyethylene technology, and involved a 4% ownership of Showa Denko by Phillips in addition to several joint ventures.

Other plastics, including teflon and acrylics, were introduced at this time. Also introduced were injection molding apparatus and other apparatus for handling plastics and fibers.

A great deal of emphasis has been given to polymer chemistry in both industrial and university sectors. All universities in Japan work on polymer chemistry, although the leaders are the former imperial universities at Tokyo, Kyushu, Kyoto, Osaka, and Hokkaido. In the case of cellulose chemistry, Professor Atsuki at Tokyo and Professor Kita at Kyoto were among the world's leaders.[13] Professor Takayanagi at Kyushu University is a world leader in polymer structure interpretation. He is also the inventor of the "Rheovibron" instrument used in the interpretation of visco-elastic properties of polymers.[14]

Today Japanese efforts in this field are extensive and significant. Major work has been done on carbon fiber, the fourth major synthetic fiber following polyester, nylon, and acrylics. Toyo Rayon has developed a high performance carbon fiber made by firing polyacrylonitrile filament, the company's own invention, at more than 2000°C.[15] It has been marketed under the trade name Torayca since August 1971, and the U.S. Department of Defense has recently offered to buy 500 tons per year for use in military aircraft. Another possible application of this fiber will be in uranium centrifuge enrichment devices. Toyo Rayon has had a mutual technical exchange contract with Union Carbide since 1970. Several other Japanese companies, such as Nippon Carbon and Mitsubishi Rayon are also involved in research on carbon fibers.

Another area of significant Japanese interest is synthetic pulp and paper, perhaps in large part due to Japan's need to import in this area. Mitsubishi Rayon has a working agreement with the U.S. company Hercules on the development of synthetic paper. The Eidai Co. has developed a new chemically embossed plastic plywood, which involves subjecting polyester to ultraviolet and electron beam bombardment, producing a feel and appearance almost indistinguishable from the natural product.[16] Mitsui Petrochemical and Crown Zellerbach have entered a joint venture to produce synthetic pulp from petroleum.[17] Japan Synthetic Paper Co., a joint venture of several Japanese companies, has developed a paper made of polystyrene film treated with ink-absorbing chemicals.[18]

In the area of machines to handle plastics, the Japanese also have developed capabilities of their own. Mitsubishi Heavy Industries is a leader in this research. They are developing an injection molding machine controlled by a minicomputer and two types of high cycle injection machines whose mold closing forces are 1200 tons and 450 tons. Nissei Plastic Industrial Co. has also developed injection molding machines very efficient in the use of materials.[19]

One polymer that is receiving a good deal of attention in Japan is polyvinylidene fluoride. Professor Wade and Dr. Fukada of Tokyo University, respected for their study of piezoelectric materials,

have been investigating the piezoelectric properties of this polymer.[20] Kureha Chemical and Pioneer Electronics in a joint development and Matsushita are developing potential applications to loud speakers and other acoustic apparatus. We should note that the Japanese have long been leaders in studying the piezoelectric properties of substances. Eguchi in the 1920's first discovered the electret, the electric analogue of the magnet. The material he used was a mixture of carnauba wax and resin. Ceramics have been the main piezoelectric material since World War II, but polyvinylidene fluoride could be a major development. The Japanese lead in the development of piezoelectric materials and devices is reflected in the U.S. patent data. Japanese scientists received 76 of the 158 U.S. patents in the area of piezoelectric compositions between 1963 and 1972, and 21 of the 34 in 1972.

6. Industrial Microbiology

The Japanese have long relied on fermentation processes to produce such foods and beverages as sake, soy sauce, and soy paste. This is perhaps the major reason the Japanese have devoted so much attention to this area, and have become the world leaders in this field.

In the 1940's and 1950's with advances in the basic understanding of microorganisms (microbes), industrial scientists were beginning to manipulate microbes more efficiently. The Japanese were quick to apply new techniques for identifying mutants to industrial production.

The early leader of this effort was S. Kinoshita, now with Kyowa Hakko Kogyo Ltd.[21] He followed up on S. Tada's 1954 discovery that l-glutamic acid, a food flavor enhancer, could be produced by bacteria. In 1957 he discovered a mutant that efficiently produced l-glutamic acid. This led to special government support of basic research on amino acid fermentation that lasted from 1957 to 1959. Research was effectively organized in the universities and government research bodies, the literature on fermentative production of amino acids mushroomed, and several new bacteria were discovered and utilized industrially.

Today the Japanese have the world's largest amino acid industry. Most l-amino acids are now commercially available. The Japanese produce

over 90% of the world's current production of lysine and are rapidly expanding capacity. This is used as a feed additive, and demand far outruns supply. The Japanese have exported lysine technology. One example is a recent joint venture in France, equally owned by Ajinomoto Co. and Les Products Organiques du Santerre.[22]

More recently emphasis has been placed also on nucleotide production, starting with flavor-enhancing nucleotides. A great deal of attention has also been paid to single-cell protein, but the problems of toxicity and the recent increase in oil prices have set this effort back.

The Japanese have also used fermentation processes to produce a variety of antibiotics. H. Umezawa is a leader in this development, the discoverer of several new antibiotics and other medicinal substances produced by fermentation.[23] In 1954 he isolated an anti-tumor antibiotic, sarkomycin, still produced today only in Japan.

In a 1968 OECD study of the pharmaceutical industry only one of the 138 major pharmaceutical innovations since 1950 was attributed to Japan: the development of Colistin.[24] Their choice of innovations probably could be disputed, and this is not an accurate indication of present capabilities. For example, Fujisawa Pharmaceutical has licensed nine foreign pharmaceutical firms to produce Cefazolin, an antibiotic developed by Fujisawa using fermentation techniques.[25]

Overall the Japanese are today active in all areas of industrial microbiology. The U.S. patent data is a good indication of this. The Japanese obtained 287 out of 1245 patents granted in the area of fermentation technology in the 3-year period ending June 30, 1973 (see Table 30). In many subareas the Japanese match the U.S. in patents, trailing seriously only in the area of fermentation apparatus where they obtained only 5% of all patents, as opposed to the U.S. 90%.

One major development in the area of automatic surveillance and screening of microbe cultures has recently taken place in Berkeley, California.[26] The Cetus Corp. has developed an automated scanning apparatus for submerged microbe culture that will eliminate much of the tedium involved in microbiological investigations, saving a large amount of labor now devoted to recognizing mutants. This will allow a much more rapid development of more useful microbes. The Japanese

have shown a great deal of interest in the apparatus. The Cetus Corp. is not selling any licenses on the apparatus, and it will be interesting to watch how long the Japanese take to develop a similar machine of their own. Because of increased labor costs and labor shortages there will certainly be a large incentive to develop a similar machine.

Table 30

PROFILE OF ACTIVITY IN FERMENTATION TECHNOLOGY

The following profile pertains to the activity of the United States and Japan in Class 195, fermentation. The sub-areas of that class are:

195A Fermentation of carbohydrates

195B Oxidative or reductive fermentation

195C Other fermentation processes involving products which do not contain a significant amount of ferment (see A and B)

195D Processes for making prefreed enzyme or malt-containing, fungi-free ferments

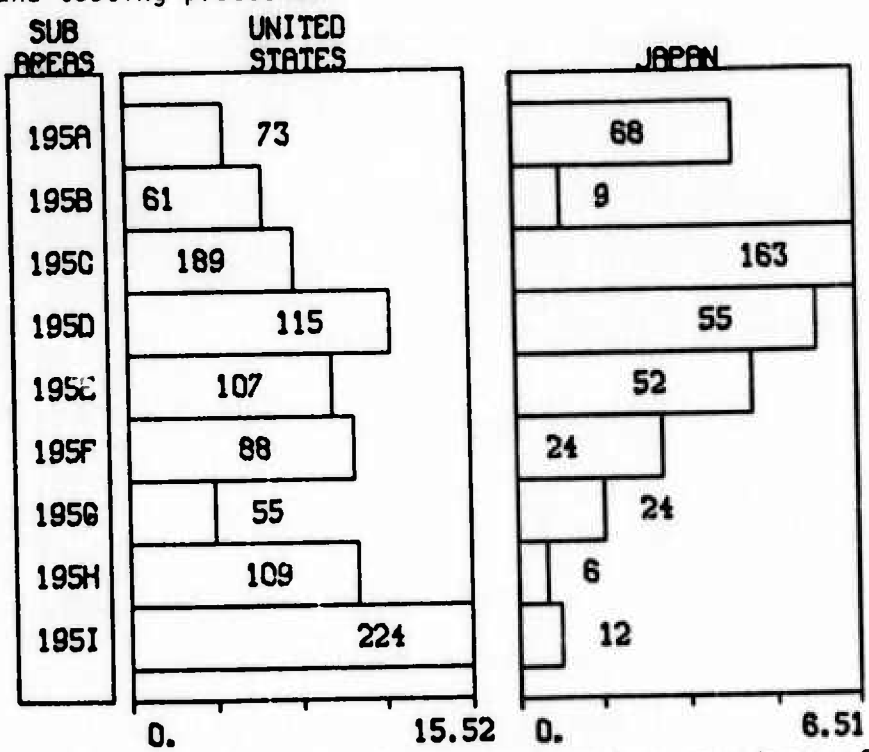
195E Processes for making living fungi-containing, malt-free products

195F Ferment containing products

195G Other fermentation processes (see D and E)

195H Fermentation apparatus

195I All other, including virus and animal tissue propagation, specialized ferment and materials, and fermentation analysis and testing processes



Bar length represents the ratio of patents issued to residents of the indicated country during the three years ending 6/30/73 to each hundred total patents in the sub-area. Number within or beside the bar represents the number of patents in the sub-area issued to residents of that country during the three year period.

SOURCE: *Technology Assessment and Forecast*, U.S. Patent Office, June, 1974.

CHEMICALS

Footnotes

1. Statistics from *R&D in Japan, 1973.*

2. Tsurumi Thesis, pp. 205-208.

3. *Technocrat*, June 1974, p. 38.

4. "Japan's Investment Rules May Face Major Test," *Chemical and Engineering News*, April 8, 1974, p. 16; "Dow Being Coy about Plans for Production in Japan," July 22, 1974; p. 4. "Dow Chemical Expects Quick Growth for New Japanese Unit," *Los Angeles Times*, August 30, 1974, p. 13.

5. "New Ethylene Technique," *Technocrat*, July 1974, p. 38.

6. "New Ethylene Process," *Technocrat*, July 1974, p. 40.

7. "More on MITI," *IEEE Spectrum*, March 1974, p. 68.

8. Chiyoda Chemical Engineering 1973 Annual Report, p. 14.

9. Tsurumi Thesis, p. 131.

10. "Japan: Now the Imitator Shows the Way," *Business Week*, May 16, 1970, p. 92.

11. Tsurumi Thesis, p. 131.

12. "Japanese Vinyl Chloride Industry and Its Present Problems," *Technocrat*, July 1974, p. 36.

13. "Trip and Meeting Report," J. W. Faull, Jr., October 1966, ONR, EXOS 3900-1, p. 3.

14. "Memorandum," A. L. Powell, December 12, 1972, ONR, p. 4.

15. "Carbon Fiber," *Technocrat*, May 1974, p. 37.

16. "Artificial Plywood," *Technology Forecasts*, January 1974, p. 14.

17. "Synthetic Pulp Venture," *Technology Forecasts*, January 1974, p. 5.

18. "Japan: Now the Imitator Shows the Way," *Business Week*, May 16, 1970, p. 92.

19. "Progress in Recent Plastic Molding Method or Machine in Japan," *Technocrat*, April 1974, p. 36,

20. Private conversation with Professor Nicholas Tschoegl, Cal Tech, and Professor Wada.

21. "Industrial Microbiology," Koichi Yamada, in *Science in Japan*, A. Livermore, 1965, Horn-Shafer Co., p. 408.

22. "Ajinomoto Enters France for Lysine," *Technocrat*, February 1974, p. 46.

23. "Industry is Finding More Jobs for Microbes," Gene Bylinsky, *Fortune*, February 1974, p. 98.

24. *Gaps in Technology: Pharmaceuticals*, OECD, Paris, 1969.

25. "Fujisawa Sells Cefazolin Know-How," *Technocrat*, February 1974, p. 46.

26. Bylinsky, *op. cit.*, p. 100.

E. ELECTRONICS AND COMMUNICATIONS

1. Statistical Overview

This sector is particularly important to Japan's increased emphasis on "knowledge intensive" areas. It is the sector that is most R&D intensive, as measured by the percentage of sales going to R&D, 3.94% in 1972.[1] While this figure is still well below the typical 8 to 10% in the U.S. industry, it has been increasing over time (see Table 31).

The government has singled this sector out for a great deal of attention, as we will see below. Only on July 1, 1974, were the remaining restrictions on technology import and on the manufacture under license of computer related equipment removed. Foreign investment will not be decontrolled for integrated circuits (IC's), computers, information processing, and precision instruments until April 1, 1976, after which time 100% investment will be permitted.

It is also an industry dominated by a handful of large firms. The seven firms capitalized at more than 10 billion yen employed 50% of the researchers, and spent 65% of the funds allocated to R&D in 1972. The five leading firms in terms of R&D expenditures spent 105 billion yen in 1972, $70 million per firm. In the examples discussed below the names of only a few large firms will occur again and again: Hitachi, Nippon Electric (NEC), Tokyo Shibaura (Toshiba), Matsushita, Sony, and Fujitsu. The five largest firms spend 5.5% of sales on R&D.

Most of the research conducted in the industrial labs is oriented to development. Basic research accounts for 7.5% of expenditures, applied research 24%, and development 68.5%.

In addition to the private sector, there are also three public corporations involved in R&D. These are Nippon T&T (NTT), Kokusai Denshin Denwa (KDD - International Radio and Cable), and Nippon Hoso Kyokai (NHK - Japan Broadcasting Corp.). Each has associated research laboratories which play important roles in communications and broadcasting, the most important being NTT's Electrical Communications Lab (ECL).

Table 31

STATISTICS ON R&D IN ELECTRONICS AND COMMUNICATIONS

Year	Number of Researchers	Expenditures on R&D (Million Yen)	Expenditure/ Researcher (10,000 Yen)	Expenditures as % of Sales
1961	5,850 (12.7)	21,799 (13.3)	373	2.20
1964	8,629 (14.6)	31,137 (12.8)	361	2.56
1967	12,925 (15.8)	55,467 (14.6)	429	2.60
1969	14,970 (15.9)	93,366 (14.9)	624	2.91
1970	18,937 (17.0)	129,845 (15.8)	686	3.06
1971	18,753 (16.6)	131,656 (14.7)	702	3.64
1972	19,374 (15.5)	164,926 (15.8)	851	3.94

SOURCE: *R&D in Japan*, 1973.

Figures in parentheses are the percentage of the corresponding number for all industries

In the research institution sector there were 1553 researchers specializing in electronics and telecommunications in 1972. Foremost here is MITI's Comprehensive Electronics Laboratory (formerly the Electrotechnical Laboratory - ETL), where a great deal of basic and applied research has been carried out, from the construction of Japan's first computer in the 1950's to coordination of MITI's Pattern Information Processing System Project (PIPS) today.

The university sector also does extensive research on the underlying basic physics and electrical engineering. Of special importance is the work on magnetic properties of materials. However, researchers in the universities suffer from lack of adequate funding. Equipment available is far inferior to that available in the large industrial labs. This may be an important factor in the fact that Japan has not pioneered in the development of new solid state and other electronics devices.

There has been extensive reliance on foreign technology in this sector, most of it coming from the U.S. Relations between the large Japanese companies and their American counterparts are particularly extensive here.

During the period 1950-1964, there were 333 type A and 14 type B licensing agreements in this sector.[2] This pattern has continued to the present time, although today most royalties are paid for basic patents and there is relatively little technical assistance involved, except for military and space applications.

In 1972 there were 94 new cases and 438 continued cases of technology import, costing 888 and 16,887 million yen, respectively. The U.S. was the source of 92% of these imports, and Europe accounted for the rest. Japan was able to export a significant amount of technology, receiving 4,185 million yen for new cases of technology export, and 841 million yen for continued cases. Almost all of this technology went to less developed areas, but detailed statistics for this sector are lacking.

Today Japan has developed significant R&D capabilities in this area, as we will see below. The traditional emphasis on consumer electronics is gradually lessening, and in the future Japan will place far greater

emphasis on industrial electronics. This is reflected in the 1972 research expenditures, with 65,826 million yen ($220 million) going to consumer electronics and 81,236 million yen ($270 million) going to communications and electronics equipment.

One statistical indication of Japanese strength is U.S. patent activity of Japanese origin. In a whole variety of subclasses this activity is significant and in many rapidly increasing over time. Many of the patent classes listed in Table 24 (Section II.G.) are in the area of consumer electronics. The Japanese obtained 42% of 1972 U.S. patents for electronic musical instruments, 40% of those for magnetic sound recording and reproducing structures, 22% of those for color television components, and 33% of those for telephone recording systems. In such new fields as holography and pattern recognition systems Japanese activity was also significant, reflecting the importance given to research in these fields in Japan.[3]

Let us now take a more detailed look at some of the sub-areas of this industry.

2. Consumer Electronics

This has long been an area of Japanese technological strength. The Japanese reputation for cleverly exploiting basic technology initially developed abroad, usually with significant improvement, is supported by examples taken from this field.

Perhaps the most famous example is the development by Sony of the transistor radio in the 1950's. The transistor had been developed by Bell Labs and the technology had been made available to all interested parties. Sony licensed the technology and set out to develop a transistor suitable for radios, devoting essentially all the R&D capability of the small firm to the development, and of course succeeding.[4]

This pattern was repeated in the development of transistor technology for television. Again Sony led the way in developing the solid state TV. More recently the Sony Trinitron TV, with one gun producing all three primary colors, was a major development in color TV.[5]

Matsushita, the other consumer electronics giant in Japan, also started out by making use of foreign technology. The company obtained

most of its postwar technology through a joint venture with Philips of Holland that began in 1952.[6] This tie-up provided access to much of RCA's patented know-how in the TV area. Today Matsushita's automated TV manufacturing facilities are the most advanced in the world. So confident is Matsushita of this lead that RCA engineers have been allowed to view the whole operation. And Matsushita has been able to export technology to the U.S. GE, for example, has bought a license to make a cheaper, more efficient zinc oxide semiconductor, used in high voltage stabilization circuits for color TV. P. R. Mallroy & Co. has also licensed some of Matsushita's ceramics technology.

The two Japanese firms also pioneered in the commercial development of video tape recorders, although the market for these instruments has yet to develop.

The Seiko watch company was a leader in electronic watch development. In 1969 Seiko introduced quartz-crystal oscillation and a complementary metal oxide semiconductor (CMOS) frequency divider to provide the timing device for a stepping motor driving a conventional display.[7] The CMOS devices were purchased by Seiko from Intersil Corp., a U.S. firm and one of the largest suppliers of CMOS watch circuits. Since that time, the U.S. companies have come to dominate the industry, since the various components are all manufactured here. However, in the development of liquid crystal displays for electronic watches, Japanese technology is said to be at least as advanced as that in the U.S.[8]

The Japanese have long been leaders in the development of acoustical equipment. Their strength in the study of the piezoelectric properties of materials was mentioned above.

Efforts are also being made to make use of the new display devices, in particular light emitting diodes, for the development of panel type TV sets. This development is still several years away, with progress needed on the LED's before it becomes a reality.

Finally, the Japanese have led in the development of commercial microwave ovens, coming up with the improvement necessary to make the microwave devices economically viable.

3. Electronic Components

In the area of electronic components there has been a technological gap between the U.S. and Japan throughout the post-war period. This gap is certainly narrowing as we shall see below. The Japanese have had to pay for basic foreign patents throughout the post-war period, with only the Esaki tunnel diode, a development of limited commercial importance, being discovered in Japan. But, unlike the case of computers, technical assistance in this field has been very limited. Almost all of the licensing has been restricted to patents. Mitsubishi did license some of TRW's high frequency device technology in the mid-1960's, and technical assistance was involved. In the late 1960's Sharp licensed custom MOS chip technology from North American Rockwell, with extensive technical assistance involved. But these have been the exceptions. This lack of technical assistance agreements may be as much a function of U.S. firms' unwillingness to take part in such ventures as a lack of Japanese desire for such agreements.

Patent licensing policy has been quite liberal in this industry ever since Bell licensed its basic transistor patents.[9] Since Bell has been responsible for a far disproportionate share of basic developments from the transistor to the charge coupled device during the post-war period, Bell's policy has had widespread effect. Fairchild and North American Rockwell have also had liberal licensing policies, but for the most part there has been a reluctance to transfer know-how, except to foreign subsidiaries. With Japanese government limitations on foreign investment in this sector, there has been little U.S. penetration. Texas Instruments in 1968 was able to use its patent leverage to gain a toe-hold in Japan in the form of a 50-50 joint venture with Sony. The price paid was the licensing of its basic IC patents to all Japanese IC manufacturers for a royalty of 3.5% of sales (Western Electric receives 2% and Fairchild 4.5%) plus market restrictions on its production of IC's in Japan (10% of the market).[10] TI has since bought out Sony, and today has 15% of the Japanese IC components market, a share likely to increase because of its greater ability at solving application problems.

The fact that the market for many devices in Japan is captive, with Hitachi producing for Hitachi, Fujitsu for Fujitsu, and NEC for NEC, does mean that these firms do not face the variety of applications demanded of U.S. firms in a "merchant" market. Other market factors, such as the greater role of government in the U.S. market, and the greater sophistication of the U.S. market, have also played a role in technological levels.

In the U.S. military and space applications have necessitated advanced components research, and this has been funded at a high level. In recent years industry has played a greater role in supporting new developments in this country, with the military market concentrating on older lines like dielectric isolated bipolar devices. In Japan military and space applications were unimportant, and most of the market for components was in consumer electronics until recently. The emphasis of research was therefore on applying existing basic technology to these applications. Funding of R&D, which was only 2.5% of sales in the mid-1960's, did not allow the luxury of much basic research.

The Japanese did develop improvements in imported components, starting with Sony's extension of the frequency range of the transistor, but lagged in all the important innovations in components. The companies with the greatest strength in components research are the companies (Hitachi, NEC, Fujitsu, Toshiba, Mitsubishi) who have concentrated on industrial electronics, especially for communications, broadcasting, and computer applications.

MITI and other government ministries have played a relatively small role in terms of funding R&D in this area until recently. Integrated circuits have been kept under foreign investment controls, but subsidies for research on basic devices have been small. ETL and ECL have, however, been leaders in basic and applied research on electronics devices throughout the post-war period, making their results available to all interested parties for further development. MITI presently is subsidizing research on IC's and software with a 3.5 billion yen budget. This includes work at Hitachi on silicon gate E/D MOS and LSI, at Toshiba on CMOS and LSI, at NEC on a high

performance linear IC for industrial use, at Mitsubishi-Oki on N channel MOS-LSI, and at Fujitsu-Sharp-Kyodo Electronics on a linear IC for industrial use.[11]

The Japanese do today have advanced capabilities in many device areas. This is indicated by increase in cross-licensing, for instance between TI and Fujitsu in the area of IC material and testing technology.[12] Cross licensing between GE and Toshiba is extensive. There has been also a recent joint research effort between GE and Toshiba which resulted in the development of a technique for the high density connection of IC's.[13] The "semiconductor thermoplastic dielectric" process will have applications in the field of microwaves. Such developments could increase in the future as a means of conserving R&D expenditures for both parties.

One example of a backflow of device technology to the U.S. occurred in the late 1960's in the area of plated wire memories.[14] Singer Librascope licensed the woven wire memory developed by KDD and Toko Radio Coil. The Japanese had not pioneered in the development of plated wire memory. Bell had developed an ROM (read only memory) for use in applications where a non-volatile high speed memory was necessary. The Japanese carried out a unique development, hoping to leap-frog existing core memories. Singer Librascope dropped out of the development, partly because of cost problems and for unrelated financial reasons. Toko does still produce an advanced plated wire memory, but the hope of replacing core memory was never realized. Most applications of plated wire have been for military systems where the buyer has been willing to pay a premium price.

Today Japanese core memories are also at world levels, reflecting their abilities in magnetic materials. Toshiba has produced some excellent CMOS chips.[15] Several Japanese firms have indicated an interest in licensing North American's silicon-on-sapphire (SOS) technology, indicating a lag in that device, which has applications in advanced calculators.[16]

In some of the new device areas whose economic significance is not yet clear the Japanese do lag the U.S. firms. This is true in the development of both magnetic bubble devices and charged coupled

devices (CCD's). Basic research on magnetic bubbles is said to be at U.S. levels, but the Japanese have lagged in development of the devices. The Japanese simply do not yet have the R&D resources to pursue all the new device areas at an intensive level.

One source felt a major problem in the development of computer memory chips in Japan was the lack of a computer aided systems design capability.[17] Thus the Japanese have had difficulties in selling LSI memories. Presently U.S. manufacturers do supply about a third of the Japanese calculator chip market.

Another source felt that the technology gap had been closed in many areas, especially semiconductor devices: bipolar, P-channel MOS, and N-channel MOS, but that the Japanese were relatively slow in getting their development work into production and incorporated into end products.[18] This slowness was attributed to the slow Japanese decision making process.

In the area of display technology Japanese work on liquid crystals was singled out as an area to watch for future developments. Toshiba's work on GaP light emitting diodes (LED's) was also singled out, although earlier in the development of LED's the Japanese experienced problems in handling the materials, GaP and GaAs, and had to pay a premium price for them in the U.S.[19] NEC has also done extensive work on GaP.[20]

The Japanese have done some important work on laser devices. Y. Nannichi of NEC is a leader in the study of the lifetime problem of (AℓGa)As injection lasers.[21] Laser work in Japan is generally centered around the application of lasers as sources in optical communications systems and for optical memories. The Japanese at such places as NEC and Fujitsu are not trying to build new lasers at different wavelengths or with novel characteristics. They are working with well known materials for the most part, and work on applications. NEC's work on $LiTaO_3$ (lithium tantalate) is said to be the best in the world.[22] The Japanese have developed Nd-YAG and ruby solid state lasers, and HeNe, HeCd, Ar ion, and CO_2 gas lasers, but have not attempted to export these devices abroad.

4. Computers and Data Processing

a. A Historical Development. As Japan set out to develop electronic computers in the early 1950's, there was some background to call upon. Fuji Electronic had built a small four arithmetic calculator using relays in 1941. Nakajima and Hazawa had worked on the use of Boolean algebra in relay contact networks.[23]

Fujitsu and ETL were the leaders in developing computers in Japan. ETL, in a project led by Professor M. Gato, built Japan's first relay computers, and Fujitsu, which cooperated on the ETL project, produced the first commercial relay computer, the Facom 128A in 1956.

The first electronic computer built in Japan was built by B. Okazaki of Fuji Film Co. in 1955, a vacuum tube computer used for the design of photographic lenses.

The first transistor computer appeared in July 1956, the ETL Mark III. This was based on the by-then obsolete point-contact transistors, which had a high failure rate, and the Mark IV, which used the more reliable junction-type transistors, was completed a year later. The Mark IV was a decimal computer with a magnetic drum memory of 1000 words. This was the prototype for several commercial computers, including the HITAC 301 of Hitachi and the NEAC 2201 and 2203 of NEC.

This was a period where ETL and the other Japanese laboratories were endeavoring to close the very large computer gap based on their own efforts. The collaboration between university, industry, and government labs was extensive during this early period. The full significance of computers had been recognized by only a few people. A great deal of basic information was available in the open literature since a great deal of the basic research was being done in U.S. universities, such as Illinois, Penn, and Harvard.

The Japanese also carried out an independent development during this period, through which they hoped to leap-frog existing western technology.[24] This development centered around the parametron device, discovered in 1954, a component consisting of nonlinear coils, a capacitor, and a resistor, and driven by a special modulated high-frequency power supply. It was very inexpensive compared to transistor logic available in the late 1950's, was simple, rugged, and reliable.

ECL and Fujitsu cooperated on the first parametron computer, ECL's Musasino-1, which appeared in 1957 and was the prototype for the FACOM 201. The parametron computer received a good deal of attention from other Japanese labs. The University of Tokyo Physics Department developed a pair of experimental parametron computers, partly in collaboration with Fujitsu. Hitachi put out a commercial model of its own, the HITAC 101 in 1959, and NEC and Tokoku University jointly built the NEAC 1102. In the long run, the large power requirements of the parametron and the decreasing cost of transistors and IC's doomed this development. But it does give insight into Japanese thinking in this area.

By 1960, faced with IBM's entry into the Japanese market, the price of which entry had been the licensing of its basic patents to Japanese firms for a 5% royalty and limitations on its growth, the Japanese firms turned to licensing agreements with U.S. manufacturers. Fujitsu, the leading Japanese innovator, was the only exception, never entering a technical assistance agreement with a foreign firm, although it did license basic patents, and did very closely follow developments in the U.S.

The basic tie-ins during the 1960's involved the following companies: Hitachi with RCA, NEC with Honeywell, Mitsubishi with TRW, Oki with Sperry Rand (in a 51-49 joint venture - Oki-UNIVAC), and Toshiba with G.E.

Throughout this period MITI was taking an active role in the affairs of the computer industry, which it recognized as being crucial to the future development of Japan. This role is described in detail in *Japan: The Government Business Relationship*, a U.S. Department of Commerce report. We will concentrate on technological developments here.

The first joint project sponsored by MITI during this period, the FONTAC project, began in 1962 and ran until 1965. It involved the development of a commercial system, with Oki and NEC sharing the hardware development and Fujitsu taking the software responsibility. It was said to be reasonably successful.[25]

By 1966 the Japanese felt that the technological lag was largest in the area of large scale computers.[26] The IBM 360 series had been

introduced and MITI decided to build a large scale computer as one of the first projects in the National R&D Program. ETL had overall responsibility for the project, and all of the Japanese computer companies took part. Thirty-three million dollars was spent over a six-year period starting in 1966, and the project was successfully completed in June, 1972, only slightly behind schedule. The first two years were spent on overall system design and development of the required components, such as high-speed, medium scale integrated circuits (MSI). Hitachi was chosen as the main contractor in 1968. NEC and Fujitsu aided with the main hardware and system software development. Toshiba, Oki, and Mitsubishi were involved with various peripheral devices, such as optical card readers, and other I/O devices. Hitachi build the disk memory.

This project allowed the various companies to gain a good deal of experience in advanced computer technology. The resulting system compared favorably with the IBM 370/165 system in speed and capacity, and incorporated features not then available on IBM machines such as virtual memory and multi-processing. The system architecture was chosen to be compatible with the IBM system 360. Hitachi has sold several of the commercial versions of this computer, the HITAC 8700/8000 system, in Japan, especially to government-related institutions like the University of Tokyo. The large-scale end of the Fujitsu 230 series, the 230-75, presumably also benefited from Fujitsu's experience in the project. This is said to be the most powerful computer available in Japan.

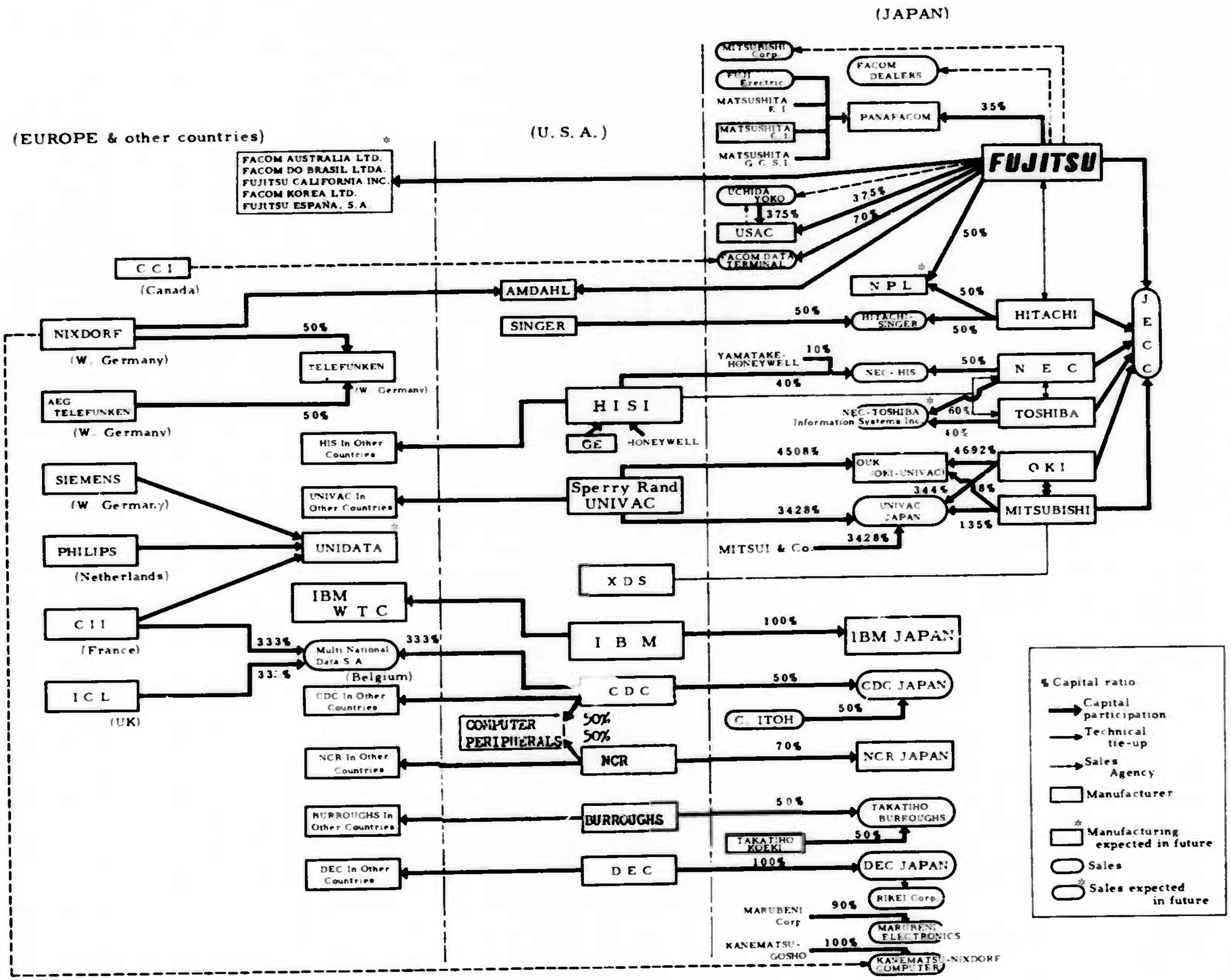
Clearly, the MITI project did develop a significant system. It did not exceed advanced U.S. systems, and it is impossible to tell how much was learned from the ongoing agreements with U.S. firms. For instance, how much had Hitachi learned from RCA about virtual memory? It was developed too late to gain a significant market share, but it may have succeeded in all but closing the technology gap at the large-scale end of the computer line. The Fujitsu-Amdahl joint development mentioned below may close the gap completely. Some have called it a mistake to place such great emphasis on the large-scale computer since the market is limited and the competition severe. But the Japanese hope that the long-term payoff in technological progress will be great.

Concurrent with the MITI project, NTT was sponsoring the DIPS (Dendenkosha (NTT) Information Processing System) project.[27] ECL was the coordinator of the project, and Fujitsu, Hitachi, and NEC took part in the joint development starting in 1969. Three sets of DIPS-I hardware, compatible at the machine language level, were produced by 1971, and software development for the NTT data communications network began then. A great deal of what was learned on the MITI project was incorporated into the NTT project, but the first version of the system did prove unsatisfactory in terms of cost, so the three companies independently went back to the drawing board to work on DIPS-II.[28] Fujitsu has apparently been able to increase speed by a factor of 2.5 over DIPS-I. DIPS-II is targeted to go into service in late 1976, and will incorporate NMOS main memories. The software for the DIPS-I version was said to be at the level of MULT!CS, IBM's VS2/TSO, or Burroughs' MCP. It includes time-shared management and inventory-control systems. It will be interesting to monitor this development, a fairly advanced application where troubles are not unexpected. It will be a good indication of Japanese software capabilities.

In 1971 Hitachi and Fujitsu began moves toward greater cooperation in computer development, manufacturing, and marketing.[29] Aside from agreeing that their next hardware generation will be compatible, there is little indication of any more extensive cooperation in R&D. It will be interesting to watch how this relationship develops. Figure 7 displays the present structure of the Japanese industry and its ties to the world industry.

MITI has sponsored the rationalization of the industry, encouraging cooperation between the members of the three combines, Fujitsu-Hitachi, NEC-Toshiba, and Oki-Mitsubishi. The greatest cooperation is in the final group, with Sperry Rand playing an important role in this effort.[30] They have jointly developed a large scale computer, Cosmo 700, to compete with the IBM 370/145. The NEC-Toshiba joint development, the ACOS series 77, models 200, 300, and 400, are quite similar to the Honeywell 200--unsurprisingly since Honeywell has had licensing arrangements with both NEC and Toshiba.

MITI continues to subsidize the development of the next computer series which will use LSI current mode logic and MOS memory technology.



SOURCE: *Fujitsu and the Computer in Japan*, A Fujitsu Publication.

Fig. 7--Structure of the Japanese computer industry as of February 1974

The hope is that this generation will be competitive with U.S. computers, especially IBM's.[31]

A major development at the large scale end of the 4th generation computers is the Amdahl-Fujitsu joint development.[32] Fujitsu had long observed the U.S. market, sending engineers periodically on extended visits to observe the U.S. computer developments. When Amdahl decided to establish his own company in order to build a super computer using the latest LSI technology, Fujitsu (and also Nixdorf of West Germany) made significant financial contributions to the effort, basically to obtain the Amdahl version of LSI bipolar, emitter-coupled logic used in the CPU of the Amdahl 470 computer.

Today this relationship has grown with Fujitsu now taking over the manufacturing of 90% of the hardware and helping to specify characteristics of the system, including virtual memory and multiprocessing. Thirty Fujitsu engineers are resident in Sunnyvale, California, working on the joint development. The first computers are due on the American market at the end of the year. Clearly, Fujitsu has gained some advanced technology in this development. Some people again dispute whether it was worth the cost.

b. Present Capabilities. In trying to assess Japanese capabilities today one runs into the maze of licensing agreements between Japanese and U.S. firms. It is clear that many Japanese developments are either directly based on that experience or are follow-up efforts. American computer scientists, when they visit Japan, notice great similarities to U.S. machines, even for those machines supposedly independently developed. For example, Hitachi produces a drum plotter, essentially identical to the Calcomp 565 plotter, though said to be a Hitachi development. Fujitsu's plasma display is much like that of Owens-Illinois, and Hitachi makes a CRT display similar to the Univac 1558 display.[33]

An example of an area where the Japanese trail is in the development of magnetic disk memories.[34] In the late 1960's both Hitachi and Toshiba took out IBM licenses on its disk memory, the 2311 and 2314. Toshiba ran into problems in meeting the tolerances on the rack and pinion system, basically due to material problems, and also

problems getting the aluminum oxide coating smooth enough. Hitachi was more successful and did capture a significant share of the market. Toshiba dropped out after producing about 1000 machines. However, by the time these developments were complete, IBM had come out with its next generation machine, the 3330. Only recently Hitachi announced that in 1975 a disk memory with a 200 million byte capacity per spindle, the same capacity as the IBM 3330-11, will be marketed.[35] Thus it is clear that the Japanese still lag in this device.

A good deal of attention has been given in Japan to developing I/O devices for handling the Japanese language. This is one of the goals of the PIPS project discussed below. This problem seems to have been left to the Japanese. The extent of IBM Japan's involvement is unclear, although it may be significant. MITI has subsidized such efforts as the development by Mitsubishi of a high performance Chinese character printer that will appear next year after software development by Nippon UNIVAC.[36]

In the hardware for the smaller computer systems the Japanese seem to be quite competitive until one gets to the microprocessors, where LSI components play a large role. Such middle level systems as the FACOM 230-25 sell very well in Japan.[37] Oki Electro's OKITAC 4300C is the leading minicomputer on the Japanese market,[38] and the Toshiba TOSBAC 40 series also is worthy of note, particularly for the large number of applications packages available with the series.[39] The Japanese have lagged somewhat in the development of microprocessors, although Mitsubishi plans to introduce a microcomputer next year comparable to the Intel 8080.[40] This will use a high speed (2 μs) 1 chip CPU, using N channel MOS-LSI technology. Toshiba has already introduced a microcomputer, the TLCS-12, which is also said to be comparable to the Intel 8080.[41]

Most peripheral devices seem to be very dependent on U.S. development, and there is presently no indication that the Japanese have pushed ahead in any area, with the possible exceptions of holographic memory and of magnetic recorders and magnetic tape, where the Japanese have long excelled on the consumer electronics side. The development of a holographic memory by Fujitsu with the help of a MITI subsidy was the first of its kind when announced late last year.[42] This is used with

the FACOM 230-25 system. Its economic significance is not clear, but it does indicate the high level of research into holography in Japan.

The Japanese seem to have fairly ready access to many U.S. peripheral developments, possibly because of the small size and intense competition between U.S. firms in this area. Oki Electric Overseas has acquired rights to the nonimpact printer developed by Electroprint, a Cupertino, California, research firm, and has a 50% interest in Okidata, the Morristown, New Jersey, firm which has acquired Bridge Data Products and the computer memory division of Applied Magnetics.[43]

In the area of systems software the Japanese capabilities are uneven.[44] This is partly due to manpower problems. The Japanese simply do not have the number of systems programmers available to produce the variety of software available in the U.S. We have been told of one example of a backflow of technology in this area.[45] RCA, just before it went out of the computer business, did attempt to pull out the small scale end of its computer series by making use of a Hitachi OS, which RCA modified and turned into RCA's OS/70. It is interesting to note that at that time (1970-71) the Hitachi OS supported a smaller number of device combinations than the RCA OS. The Japanese tended to standardize on a given combination, probably hoping to cut down software costs, but possibly also giving less variety to customers. This tendency to standardize has also been a characteristic of the large scale computer projects.

In the use of virtual memory and multiprocessing Japanese capabilities seem to be significant, and overall their batch operating systems are up-to-date.[46]

In the area of time sharing systems the Japanese have had problems. Part of this has been attributed to Japanese communications laws and the attitude of NTT, which put restrictions on the use of telephone lines for data communication.[47] This was ended in 1972, and in 1973 after changes in the NTT switching system were made, private commercial time sharing bureaus began to operate. As mentioned earlier, NTT presently is working to upgrade its time sharing capabilities. It presently offers the DEMOS scientific and engineering time sharing service, which will be upgraded by the DIPS project systems. NTT also uses its system to provide a car registration and inspection network to

the Ministry of Transportation. A future nationwide banking network, being developed by Fujitsu in cooperation with NTT, will be as sophisticated as those available elsewhere. One should also note that less familiarity with keyboards in Japan, usually the major I/O device in time sharing systems, is also a major problem in developing time sharing.[48]

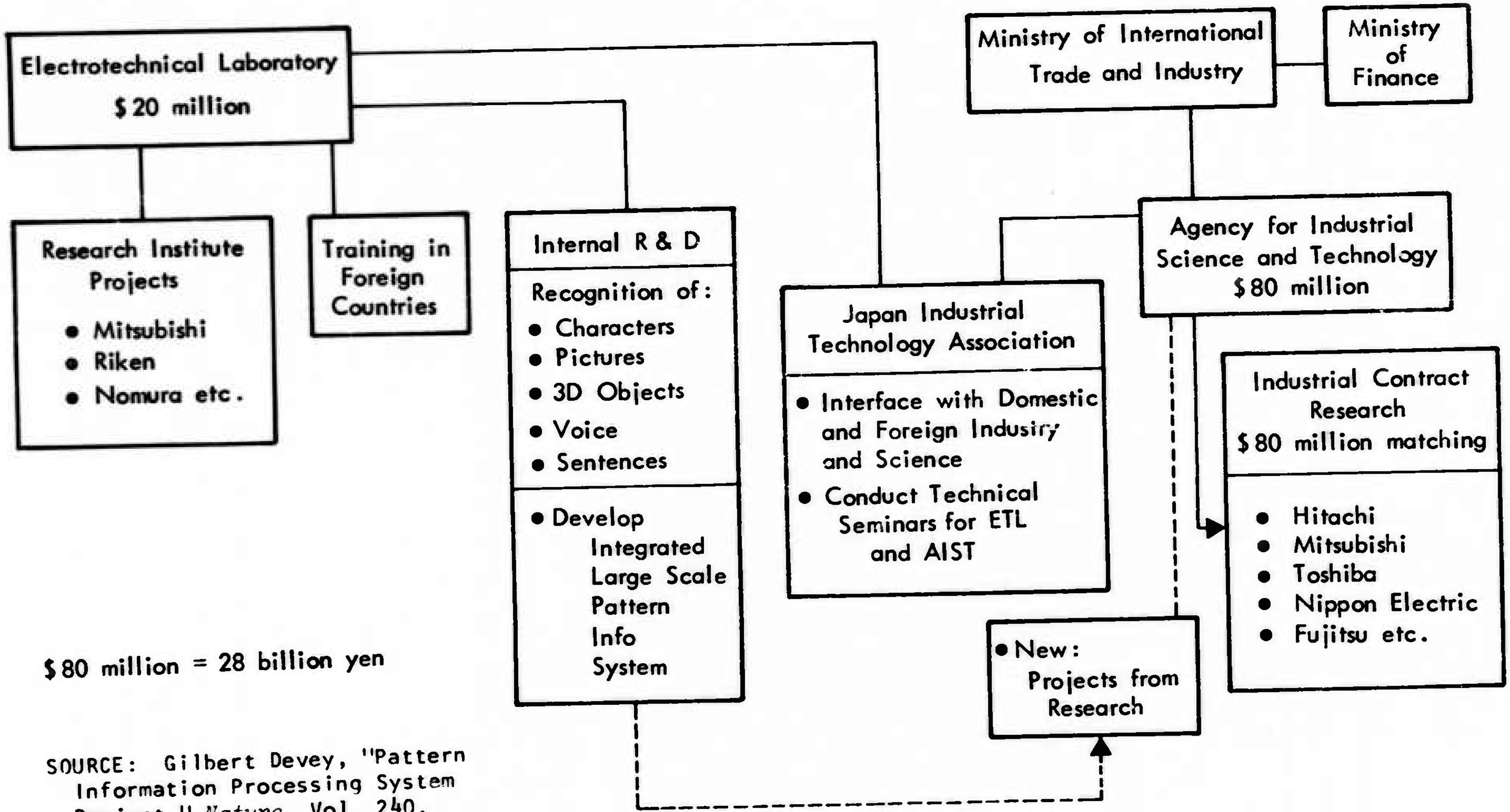
There are several other interesting computer systems operating in Japan, a few as advanced as available anywhere. The University of Tokyo's double HITAC 8700/8800 system, operating since early 1973 and used for scientific research, is an extremely powerful system. Two IBM 360/50 computers play an integral role in the operation of NHK.[49] Together with two IBM 1800 process control computers and several IBM 2250 interactive displays with light pens, the computer schedules and controls virtually all their main broadcast equipment. IBM has certainly played a major role in developing computer applications in Japan, another example being Japan Airlines' seat reservation system, but a great many interesting applications involve the Japanese companies.

Process control is becoming increasingly important in industry, with such companies as Nippon Steel and Toyota Machine Works making extensive use of process control computers in their operations. Mitsubishi has been using minicomputers to schedule and control elevators in some large hotels.

Some of the most interesting computer applications in Japan are in the area of traffic control. JNR's COMTRAC system has completely automated the operations of the famous bullet trains.[50] Hitachi is responsible for the computer system. In the area of road traffic control, the Japanese are said to be world leaders.[51] Professor H. Inose of Tokyo University has been the leader in the development of the Tokyo traffic control system, with NEC serving as the main subcontractor. The system is said to be more advanced than any available in the U.S. However, the problems are also much more severe, with a much higher ratio of cars per mile of road in Japan. The priority given to road traffic control in Japan is indicated by the fact that MITI started a big project in this area in 1973. U.S. interest in this development is indicated by the fact that the Department of Transportation is paying for the translation of Inose's and T. Hamada's book on road traffic control.

c. Artificial Intelligence and Pattern Recognition. The most significant Japanese effort in computer applications at the present time is in the area of artificial intelligence and pattern recognition. The latest MITI big project in the computer area is the Pattern Information Processing System (PIPS) project.[52] This has received the highest funding of any MITI project, 35 billion yen ($117 million) over the seven-year (1971-1978) period. This is the largest government R&D project ever undertaken outside the fields of nuclear energy and space. Its overall goal is to give the Japanese a lead in at least the applied areas of artificial intelligence. Dr. H. Nishino of ETL directs the project, which has 5 specific goals: (1) recognition of 2000 printed characters at a rate of 1 page per second, including Chinese characters, (2) recognition of 3-D objects, (3) recognition of pictures, (4) recognition of voice, and (5) recognition of sentences. These capabilities, once developed, will be incorporated into robots and other systems for industrial use. Clearly, a good deal of emphasis is being given to the peculiarly Japanese problem of handling their complex written language. Figure 8 shows a partial organization chart of the project. Industry is expected to contribute 28 billion yen, so that the total effort involves expenditures of more than $200 million. Basic research in all areas of pattern recognition is going on at ETL, ECL, and also some university labs, although the connection of university people to the project is apparently informal. Dr. T. Itakura of ECL is a leader in the area of speech processing, and the work in this area is at U.S. levels.[53] The Japanese seem to follow the lead of MIT and Stanford very closely, perhaps because so many of them were educated there, and thus far no significant contributions have been made to the major software or theoretical aspects of artificial intelligence.[54] The emphasis is on industrial applications.

There are already several interesting AI applications in Japan. The greater flexibility of the labor force may allow (and the current labor shortage may induce) the rapid introduction of many labor-replacing devices. Optical Character Recognition has been used since 1971 in Japanese postal systems.[55] The system, developed by NEC, recognizes the equivalent of a zip code, cancels and routes the letter to the appropriate post office, with only occasional human



$80 million = 28 billion yen

SOURCE: Gilbert Devey, "Pattern Information Processing System Project," *Nature*, Vol. 240, November 24, 1972, pp. 212-213. By permission of the author and *Nature*.

Fig. 8 — Organization of the PIPS project (incomplete)

intervention. 20,000 to 30,000 pieces of mail are processed each hour.

The Japanese have developed several interesting robots. One displayed in 1974, the Hi-T-Hand Expert 1, built by Hitachi, has received considerable attention. It has two hands and can insert pistons into cylinders (a 20 micron clearance) more quickly and more deftly than can be done by human hands. Other Japanese robots have been reviewed by J. Gleason in *Sigart Newsletter*, April 1973.

d. Concluding Remarks. Overall Japanese computer and information processing capabilities still lag behind those of the U.S. Many people in the industry are apprehensive about the end of foreign investment controls in 1976.[56] They fear Japanese users may turn to U.S. companies to get answers to their information processing problems. The U.S. companies will have greater experience because of dealing with the more sophisticated U.S. market. The Japanese will have hardware that will be competitive in performance, if not cost. Software will continue to be a problem. The flow of technology will continue to be one-sided. But it is unlikely that changes will come abruptly, and the computer industry in Japan will continue to be subsidized by the government and by the more profitable divisions of the large electronics firms for the foreseeable future.

5. Communications

The Japanese today have advanced capabilities in all areas of communications including data and optical communications. The extent of historical dependence on imported technology has been difficult to separate from other electronics areas, so we will concentrate on relatively recent developments. It is likely that the dependence on foreign technology is less here than in other electronics areas. One indication of Japanese strength is the U.S. patent activity in the areas of telegraphy and telephony. The Japanese also clearly have a telephone system that far exceeds the European systems, and is second in the world to the Bell system.

NTT has been developing much of its own hardware since the war, in cooperation with the major electric firms, NEC, Fujitsu, Hitachi,

and Oki.[57] In 1954 its first electronic switching system (ESS) using wired logic and parametrons for control elements was designed. The first major change came in 1964, when the DEX-1 system, featuring stored program control was begun. The most recent commercial version of ESS is D-10, which has a main memory, using ferrite core and plated wire, and an inexpensive drum memory. It provides abbreviated dialing, automatic transfer, conference calling, and call waiting, plus the ability to operate with video and data communications services. The system can handle 30,000 subscriber lines and began service in December, 1971.

NTT, in cooperation with industry, has also developed advanced data communications systems.[58] By 1972 NTT could offer a wide range of signalling rates: 50, 100, 200, 1200, 1400, and 4800 bits/sec using voice channels. NTT also offered a 48K bit/sec wide band, data transmission system, using VSB AM modulation. The modems that interface the digital equipment and the telephone lines were developed in Japan. They do in some cases use American components. North American Rockwell has sold MOS devices to NEC for use in high speed modems. Codex Co. of the U.S. has built the highest speed (9,600 bits/sec) audio data transmission system operating in Japan.[59] But NTT should soon have a similar system.

NTT is also developing a multiplexed data transmission system, the DDX-1, scheduled for service in 1976.[60] This will electronically switch lines in a time-shared manner.

In the late 1960's NTT and NEC were leading the world in the development of point-to-point free space communications.[61] This approach to optical communications was dropped when it became clear optical fiber communications were more likely to provide the high density, short range communications capability. The market for a commercial optical communications system would be enormous, and so this has received heavy emphasis. Japanese work on optical communications via fibers is first rate, and is often singled out as something to watch.[62] Nippon Sheet Glass, in cooperation with NEC (both are members of the Sumitomo group), has developed the SELFOC optical fiber, which received a good deal of attention. Its chief virtue is a lack

of dispersion of the wave pulse. But attenuation is still a problem. Corning Glass and Bell have developed optical fibers with much lower loss, some as low as 1.2 db/km.[63] One source felt that while the Japanese optical communications work was very good, they will have great difficulty competing with the American giants like Bell. It is an area to be closely watched, although commercial systems are several years away.

Japanese industry, in cooperation with NTT, NHK, and KDD, has also developed pulse code modulators with advanced capabilities. Of special note is the Fujitsu-KDD PCM TDMA satellite communications system.[64] This is among the most efficient of all international satellite communications systems.

ELECTRONICS AND COMMUNICATIONS

Footnotes

1. Statistics here and below from *R&D in Japan, 1973.*

2. Tsurumi thesis, pp. 205-208.

3. Statistics from *Technology Assessment and Forecast*, December 1973 and June 1974, U.S. Patent Office.

4. For a review of this development see "Managing Product Development for Growth (History of Sony Corporation)," M. Ibuka, in *Gaps in Technology: Electronic Components*, OECD, 1969, pp. 153-163.

5. Private communication, Professor G. Pearson, Stanford University.

6. Matsushita's history is reviewed in: "A Japanese Champion Fights to Stay on Top," Louis Kraar, *Fortune*, December 1972, pp. 94-103.

7. "The Electronic Watch," Marce Eleccion, *IEEE Spectrum*, April 1973, p. 28.

8. Private communication, G. P. Lemberg, Quantum Science Corporation.

9. *International Diffusion of Technology: The Case of Semiconductors*, J. E. Tilton, Brookings Institution, 1972, p. 77.

10. *Ibid.*, p. 147.

11. "Subsidy on IC and Software," *Technocrat*, May 1974, p. 32.

12. "Japan: Now the Imitator Shows the Way," *Business Week*, May 16, 1970, p. 92.

13. "High Density Connection for IC's," *Technocrat*, April 1974, p. 26.

14. Private communication, A. Kolk, C.D.C.

15. Private communication, G. P. Lemberg, Quantum Science Corporation.

16. Private communication, R. Doty, N. A. Rockwell.

17. Private communication, R. Doty.

18. Private communication, G. P. Lemberg

19. Private communication, G. P. Lemberg.

20. Private communication, Professor W. Bridges, Cal Tech.

21. Private communication, Professor G. Pearson, Stanford.

22. Private communication, Professor W. Bridges, Cal Tech.

23. For a review of the early history of Japanese computer developments see: "Some Important Computers of Japanese Design," H. Takahasi, p. 692-697, *First U.S.A.-Japan Computer Conference Proceedings*, 1972, Hitachi Printing Co., Tokyo, Japan. We use this extensively here and below.

24. *Ibid.*, and private communication, Professor F. Humphrey, Cal Tech.

25. *Japan: The Government-Business Relationship*, U.S. Department of Commerce, February 1972, p. 88.

26. For a review of this project see "The Development of the High Speed National Project Computer System," Nakazawa, et al., pp. 173-181, *First U.S.A. - Japan Computer Conference Proceedings*.

27. For a review see: "A Large Scale Data Processing System DIPS-I," Takashima, et al., pp. 193-202. *First U.S.A. - Japan Computer Conference Proceedings*.

28. "Japan Goes Industrial," D. Christiansen, *IEEE Spectrum*, December 1973, p. 47.

29. This is stressed in a National Research Council Report, "The Computer Industry in Japan and Its Meaning for the U.S.," NRC, 1973, PB-220000. The extent of cooperation is apparently not as great as the original pronouncements would have led one to believe. *Ibid.*, p. 47, and private communication, N. Ukai, Fujitsu Calif. Inc.

30. "The Computer Industry in Japan and Its Meaning for the U.S.," NRC, p. 67.

31. Christiansen, *op. cit.*, p. 47.

32. N. Ukai, Fujitsu, Calif. Inc., private communication. For a description of the system, see "Packing for a Super Computer," R. J. Beall, Amdahl Corp., 1180 Kern Ave., Sunnyvale, Calif. 94086.

33. Examples taken from "Trip Report for U.S.A. - Japan Computer Conference, Tokyo, Japan," Dr. Prentiss Knowlton, JPL Interoffice Memo, November 13, 1972.

34. Private communication, Dr. Okitsuga Furuyo, Cal Tech.

35. "Development of a New Disk Device," *Technocrat*, July 1974, p. 32.

36. "Chinese Character Printer," *Technocrat*, July 1974, p. 32.

37. "IBM's Offensive in Japan," *Technocrat*, January 1974, p. 27.

38. "Best Selling Minicomputer, the Okitac 4300C," *Technocrat*, April 1974, p. 32.

39. "Tosbac 40 Accepted Over 100 Orders," *Technocrat*, May 1974, p. 32.

40. "Mitsubishi's High Speed 1-Chip CPU," *Technocrat*, April 1974, p. 32.

41. "One Chip Micro Processor," *Technocrat*, May 1974, p. 32.

42. "Practical Holographic Memory," *Technocrat*, March 1974, p. 32.

43. "Japanese Aim for World Markets," E. Yasaki, *Datamation*, July 1974, p. 98.

44. "The Computer Industry in Japan and Its Meaning for the U.S.," NRC, 1973, pp. 86-90.

45. Private communication, Dr. D. Williams, JPL, previously of RCA.

46. "The Computer Industry in Japan and Its Meaning for the U.S.," NRC, 1973, p. 87.

47. "Computer Science in Japan," Richard Lau, ONR-34, June 26, 1973, p. 2.

48. Private communication, N. Ukai, Fujitsu California.

49. Examples taken from "Trip Report for U.S.A. - Japan Computer Conference, Tokyo, Japan," Dr. Prentiss Knowlton, JPL Inter-office Memo, November 13, 1972, p. 9.

50. "Comtrac -- A Computer Aided Traffic Control System for Shinkansen," Ishihara, et al., p. 466-471, *First U.S.A. - Japan Computer Conference Proceedings*.

51. Private communications, Professor E. Posner, Cal Tech, and Professor J. Pierce, Cal Tech.

52. For a description of the PIPS project goals see "Pattern Information Processing System Project," Gilbert Devey, *Nature*, Vol. 240, November 24, 1972, pp. 212-213.

53. Lau, *op cit.*, p. 7.

54. "Robot Research in Japan," J. Gleason, *Sigart Newsletter*, April 1973, p. 16.

55. "U.S.A. - Japan Computer Conference Technical Tours," A Conference Brochure, pp. 22-25. Also mentioned in Knowlton, *op. cit.*, p. 6.

56. Private communication, Dr. Okitsuga Furuya, Cal Tech and others.

57. Christiansen, *op cit.*, p. 50.

58. "Development of 48 K bit/s Data Transmission System in NTT," Ishlkawa, et al., pp. 508-513, *First U.S.A. - Japan Computer Conference Proceedings*.

59. "Super High Speed Online Service," *Technocrat*, July 1974, p. 32.

60. "Digital Data Switching System," *Technocrat*, July 1974, p. 32.

61. Private communication, Professor W. Bridges, Cal Tech.

62. W. Bridges and G. P. Lemberg, private communications.

63. Private communication, Richard Knock, Stanford Research Institute. This was announced at the Kyoto International Glass Fair.

64. Fujitsu publication, "Fujitsu: A Pioneer in the Information Age," p. 16.

F. Space

In developing their space program the Japanese chose to take an independent course until the late 1960's when the decision was made to seek U.S. technical assistance so that Japan could take part in the important applications of the 1970's, all of which require geostationary satellites. The eventual goal is still very clearly technological independence, and the present joint efforts are aimed at raising Japanese technological levels.

Through the late 1950's and early 1960's the Japanese space program was funded at a very low level. In 1961 the government budget was only 513 million yen, which was .2% of total R&D spending in Japan that year. The total space budget, government and industrial, grew to 23 billion yen in 1971 and 31.5 billion yen in 1972, but this is still only 1.8% of total R&D expenditures in 1972.[1] In 1973 and 1974 the government's space budget continued to increase rapidly, reaching 52.2 billion yen in 1974 (see Table 11).

With funding at such a low level results were also meager. Throughout the period university involvement has been very strong in the rocket development program. The Institute of Space and Aeronautical Science at Tokyo University coordinated rocket research, producing a series of sounding rockets in the 1960's, that culminated in the launch of Japan's first satellite, Osumi, on February 11, 1970. All of the Japanese rockets were multi-stage solid propellant type. The rocket that launched Osumi was the last of the lambda series, the L-4S-5, a 4-stage solid propellant rocket. The first Tokyo University scientific measurement satellite, the Shinsei (New Star), was launched in September, 1970, with the 4-stage mu rocket, the MU-4S-3, a solid fuel rocket with a lift-off thrust of 187,000 lbs. The Shinsei weighed 70 kg.

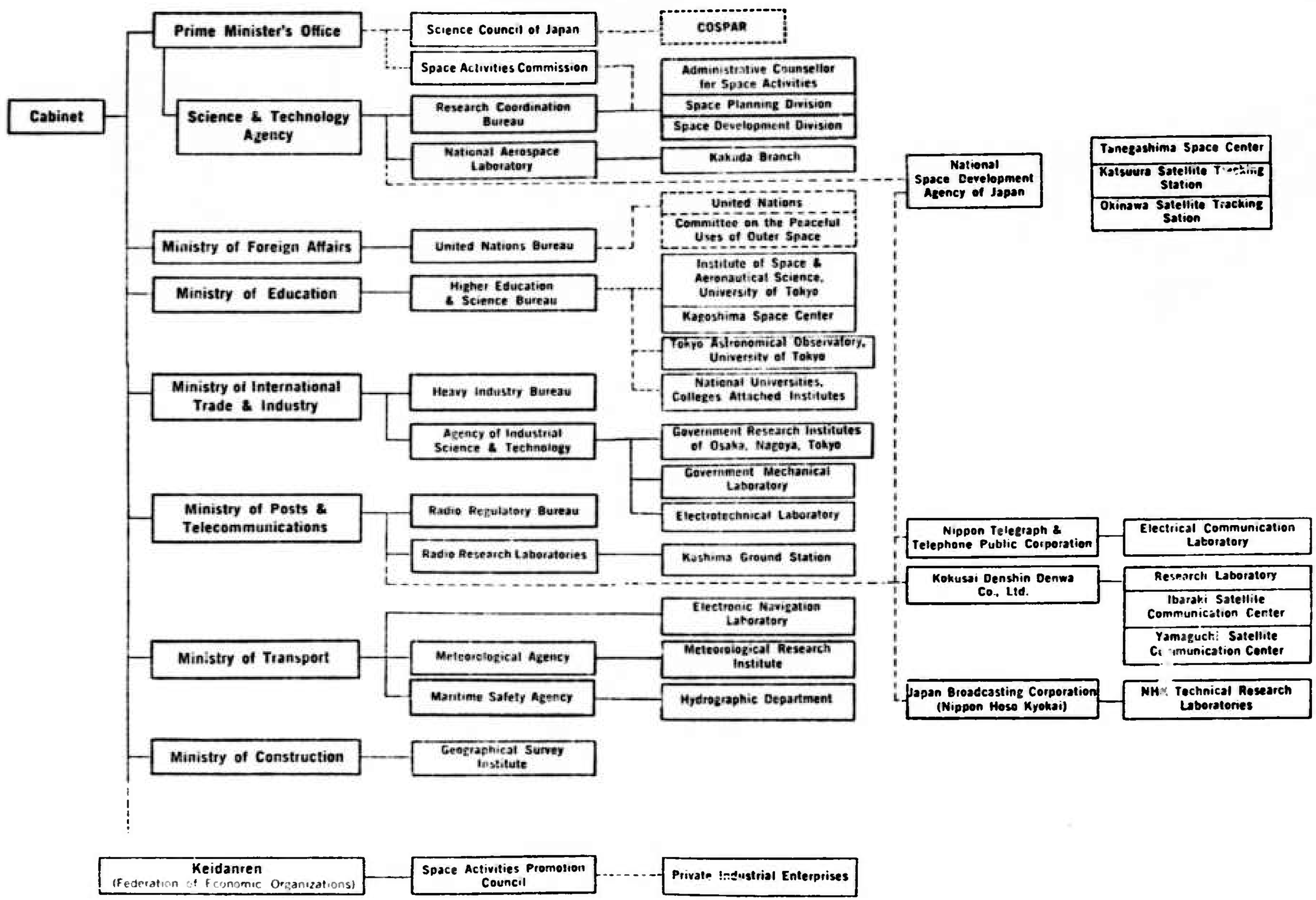
The rocket development fell far behind schedule in the late 1960's, and by 1970 Japanese goals were scaled down.[2] The original goal of a self-developed rocket with 700,000 lb. of lift-off thrust by 1974 was changed to an "N" rocket with 170,000 lb. lift-off thrust, developed by 1975 with U.S. technical assistance. This rocket with strap on boosters will have the capability of placing approximately 100 kg. in geosynchronous

orbit, about the same as the U.S. Saturn II. The "N" rocket project has involved a large amount of technical assistance from such U.S. firms as McDonnell Douglas and North American Rockwell. The Thor Delta guidance control system has been made available, as well as Thor Delta first stage technology. The "N" rocket will be the first Japanese rocket using liquid fuel in the first two stages.

Guidance control was apparently one of the major reasons for Japanese failures in the late 1960's. Japanese university scientists were apparently very conscious of the military applications of this technology, and its development was very slow.[3] The fact that the Defense Agency was excluded from the space program also slowed development. There apparently was greater expertise at the Defense Agency on both liquid propellants and guidance, due to previous U.S. military assistance programs.

Another major problem was lack of coordination in the limited effort. The organization chart for the Space Program (Figure 9) shows the large number of government agencies involved. On the industrial side the effort was also fragmented with a large number of firms involved and coordination difficult. It was government policy to spread the industrial effort around so as to bring up the technological capabilities of several firms, and industry cooperated willingly for reasons of technical prestige. The decision to import know-how from the U.S. was a victory for industry over the university researchers. Moreover, NASDA, National Space Development Agency, established in October, 1969, has taken over a large role in managing and developing the space program in the hopes of providing better coordination. The Japanese seem to be slowly and painfully attempting to learn the management of such large scale projects, and gaining the necessary systems engineering capabilities.

The present domestic effort centers around the "N" rocket.[4] It will be used to launch a series of satellites in 1976 and later, among them the ETS-2, which will go into geosynchronous orbit. It is aimed at acquiring the technology for placing satellites in stationary orbit. This program is behind schedule and having difficulties. Mitsubishi is the main contractor, but as usual a large number of firms are building



SOURCE: *Space in Japan, 1970*, Science and Technology Agency.

Fig. 9--Space-related organizations in Japan

bits and pieces of the satellite. One American scientist felt that this was not the way to go about building a high-reliability, long-lived satellite, or any advanced system for that matter.[5] The Japanese may be learning that lesson painfully. The program could well run 2 or 3 years behind schedule.

In addition to these efforts, the Japanese will also jointly develop larger satellites for immediate applications.[6] These were scheduled to be launched from Cape Kennedy in 1976 on Thor Delta 2914 rockets at $10 million per shot. But the Japanese have recently requested a delay to 1977-78.[7] All the satellites weigh 340-360 kg and will be launched into stationary orbit. This is well beyond Japanese rocket capabilities.

The goal of this program is to bring Japanese firms closer to U.S. technological levels. Japanese involvement in the three satellites is fairly small. One "joint" effort involves Hughes and NEC. This is for the development of a meteorological satellite, and 98% of the system will be produced at Hughes. This will become part of the Global Meteorological Satellite System. The cost is about 8 billion yen.

The second satellite is a communications satellite, built by Mitsubishi and Philco Ford. NEC and NTT will develop two of the eight repeater systems in the satellite, but most of the hardware will be U.S. produced. The cost is 11 billion yen.

The final satellite is a broadcasting satellite, built by Toshiba and G.E. Eighteen percent of this satellite will be built in Japan. This contract was awarded to this group over a TRW-Mitsubishi proposal, because of G.E.'s "established reputation concerning 3-axis position control techniques." The cost of the satellite will be 13 billion yen.

SPACE

Footnotes

1. Statistics from *R&D in Japan, 1973.*

2. *Aviation Week and Space Technology*, "Realigned National Space Program Adopted," November 1, 1971, p. 65.

3. Private communication, Dr. S. Uehara, Cal Tech.

4. H. Shima, *Nature*, "Japan in Space," Vol. 240, November 24, 1972, p. 240.

5. Private communication from Hughes scientist (S. Petrucci).

6. "Japan's Space Development," *Technocrat*, April 1974, p. 27 and "Japanese Artificial Satellites Come on Stage," *Technocrat*, May 1974, p. 26.

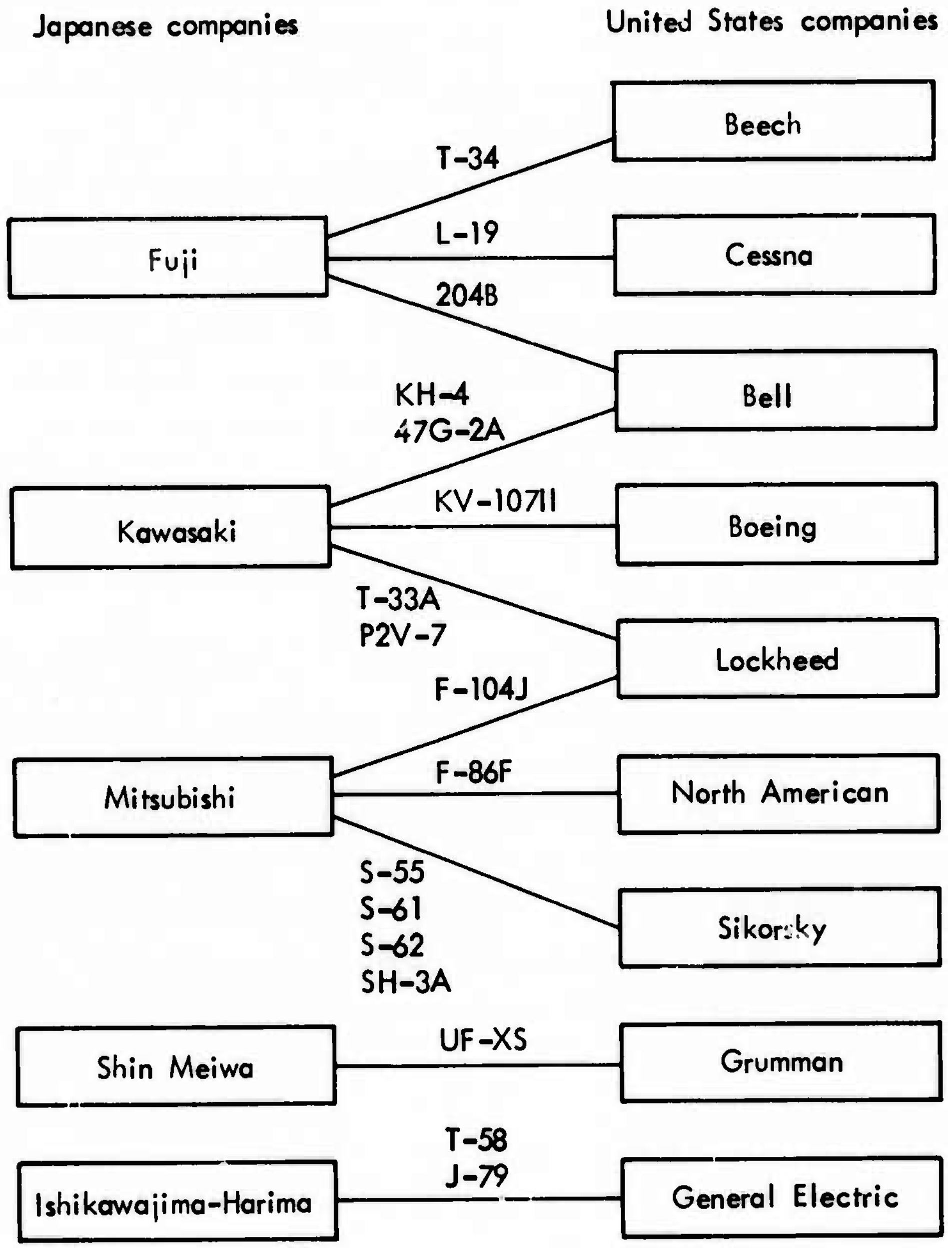
7. "Wide Expansion of Earth Satellite Network," Victor McElheny, *The New York Times*, January 21, 1975, p. 15.

G. Aircraft

Since 1952 when Japan was again allowed to build aircraft, the Japanese have largely relied on foreign licenses to develop their aircraft industry, although domestic design projects have increased over time. There has been a strong emphasis on military aircraft, with only one major domestic effort to develop a commercial aircraft, the YS-11. Funding of R&D has been meager, to the frustration of Japanese aeronautical engineers, who feel they could develop aircraft if given sufficient funding.

The government has chosen only to keep a hand in this industry, not to try to compete with countries who for reasons of military defense spend vast amounts of money on aviation R&D. In Japan less than 1% of GNP goes to defense, the lowest figure of any developed nation. And even this small amount of defense spending is a very politically sensitive issue, as last summer's bombing of Mitsubishi's offices in Tokyo attests. Without military application spurring new technology, the Japanese aircraft industry works at a serious disadvantage.

When the industry was revived in the mid-1950's, it did have its pre-1945 experience to call upon as it set out to build aircraft under license. Figure 10 shows the extensive amount of licensing in the period through 1966. Hall and Johnson have studied a few of these cases in detail: the F-86F, the T-33A, the P2V-7, and the F-104J.[1] Technical assistance was massive. But through such programs the Japanese did acquire airplane manufacturing capabilities, and they soon set out to develop their own designs, based on the know-how transferred in the military aircraft programs. It is interesting to note also the specialization of the Japanese manufacturers that developed over time, with governmental approval. MITI assigns prime contractors, and makes sure that production is divided among the first line companies so that each has a viable workload. MITI also controls entry to the industry. Fuji has concentrated on trainers, Mitsubishi on fighters, Kawasaki on transports and helicopters, Shin Meiwa on amphibious aircraft, and IHI on jet engines.



Source: G.R. Hall and R.E. Johnson, Transfers of U.S. Aerospace Technology to Japan, The Rand Corporation, P-3875, July 1968, p. 13

Fig. 10— U.S. planes, helicopters and engines manufactured in Japan (through 1966)

By the late 1950's the Japanese had developed their first domestic airplane, the T-1 jet trainer, a Mach .83 plane. Only 60 were built, the first 40 using an Orpheus engine, the last 20 a Nihon Jet Engine Co. developed IHI J3 jet engine.

In 1959 with the establishment of Nihon Aeroplane Manufacturing Co., primarily as a design bureau for commercial transports, work on the YS-11, Japan's first commercial transport, began. This was a twin engine turboprop transport with a 60 passenger capacity, designed for short hauls, i.e., conditions in Japan. It incorporated know-how gained from the military aircraft experience. The landing gear was an adaptation of that used on the P2V-7.[2] Since it came along too late it never captured much of the market, and losses on the program were about $130 million.[3] Twenty-one of the 180 planes produced were sold to Piedmont Airways in the U.S.

No other large commercial transport has been developed in Japan. For several years the Japanese have been negotiating with Boeing on a possible joint development of an intermediate range airbus. This venture is apparently now close to getting under way, with the Japanese taking a 20% share, Boeing 51%, and AeroItalia 29%.[4] The goal of the project for the Japanese is to gain know-how for future developments.

Two small aircraft developed in Japan have had success on world markets, the Fuji FA-200 Aero Subaru and the Mitsubishi MU-2. Both have U.S. engines. Mitsubishi assembles planes for the U.S. market in San Angelo, Texas.

On the military aircraft side there have been several domestic developments that are now coming into production. One is the C-1 medium range transport, designed by Nihon and built by Kawasaki. The engines for this plane, two Pratt and Whitney JT8D-9 turbofan engines, are built under license by Mitsubishi. The plane has had excellent test performance.[5]

Shin Meiwa and the Defense Agency developed the PS-1, a sophisticated long range ASW seaplane, that has aroused U.S. Navy interest.[6] Dr. Kikuhara played an important role in the design. A Grumman UF-1 Albatross was used as the experimental aircraft to be modified. The most advanced of the design concepts is a boundary layer control and

deflected slipstream system for STOL performance and greater stability in high seas. An IHI-built GE T58-10M-1 engine is housed on the upper center of the fuselage to provide power for a boundary layer control system on rudder, flaps, and elevators. Its performance capabilities are outstanding, and Grumman has U.S. licensing rights.[7]

The T-2 two-seat jet trainer and the FS-T2 single-place close-support fighter were developed after a major research effort that involved the Defense Agency, the National Aerospace Lab, and industry. Dr. K. Ikeda was design leader. This Mach 1.63 trainer was the first supersonic aircraft designed in Japan. It bears a strong external semblance to the Anglo-French Mach 1.63 Jaguar advanced jet trainer. Both are powered by two Rolls-Royce/Turbomeca Adour turbofan engines. Mitsubishi is prime contractor, basically because the trainer will be modified for use as a close-support fighter. There was apparently disappointment at Fuji about this decision.[8]

These developments indicate that the Japanese do have capabilities in designing airframes. Their best effort has been the PS-1. For advanced fighters they are still dependent on U.S. licenses, with Mitsubishi presently building the Phantom F-4EJ in Japan under a McDonnell Douglas license, and with significant technical assistance. Technical assistance is less than in the F-104J case, but still extensive.

The government did fund some research of VTOL flying test beds at both NAL and the Defense Agency's third Research and Development Center. The Defense Agency program was suspended because of lack of funds, and the NAL program is at a low level of effort.

One major effort at the moment is a MITI-sponsored big project for the development of a high-bypass-ratio turbofan engine. This project started in 1972, with the main participants NAL and IHI. The IHI/NAL FJR710 engine is said to be comparable to the G.E. TF-34 engine.[11] The only previous domestically developed engines were the IHI J3 and the VTOL engines. Thus this project is clearly relying on experience gained from building engines under license. The engine is designed for endurance during frequent takeoffs and landings, fuel economy, low pollution, low noise level and low engine temperature. This engine

and modified versions of it will have several possible applications. One will be for the PXL ASW patrol aircraft presently being developed to replace the Lockheed/Kawasaki P-2J's.

The Defense Agency has been the main force in trying to increase R&D expenditures on aviation so as to raise technological capabilities. It would like to be better funded, but has not been so far because political considerations demand a low defense budget.

AIRCRAFT

Footnotes

1. G. R. Hall and R. E. Johnson, *Transfers of U.S. Aerospace Technology to Japan*, The Rand Corporation, P-3875, July 1968.
2. *Ibid.*, p. 25.
3. T. Sato, "Japan Wants to Build Up Aircraft Industry," *Los Angeles Times*, August 26, 1974.
4. *Ibid.*
5. *Ibid.*
6. *Aviation Week and Space Technology*, "New Hardware Planned for Japan Defense," November 1, 1971, p. 48.
7. *Aviation Week and Space Technology*, "New Programs Entering Production Stage," November 1, 1971, p. 72.
8. Dr. S. Uehara, Cal Tech (and Japan Defense Agency), private communication.
9. *Aviation Week and Space Technology*, "Japanese Press Avionics Growth," November 1, 1971, p. 42.
10. Uehara, private communication.
11. *Ibid.*

H. ENERGY

Japanese efforts in energy technology research and development have concentrated on nuclear energy technology. MITI has started the "Sunshine Project" in 1974, a project designed to develop new non-nuclear sources of energy. The level at which this project will be funded is unclear at present. The emphasis will be on solar energy, geothermal energy, coal liquefaction and gasification, the efficient use of waste heat, and the possible role of hydrogen as fuel. The Japanese have also had a long-term interest in the efficient use of electricity using superconducting technology. MHD research has been funded at the level of a MITI big project, and another MITI big project on cryogenic power transmission will begin next year. Given Japan's present dependence on imported oil to serve her energy needs, energy R&D will be an important area of research in the future.

1. Nuclear Energy

Japan has relied on the introduction of foreign technology to provide its present nuclear energy capacity. Table 32 outlines the 66 type A licensing agreements concluded in atomic energy technology through the end of 1971. These licenses have cost Japanese companies over 11 billion yen, but that has been a very small fraction of the original development cost of this technology, and Japanese manufacturers have obtained significant capabilities in conventional reactor technology and in nuclear fuel cycle technology.

While working to master the conventional light water reactor technology, the Japanese have also set out on domestic development programs to develop advanced reactors, to obtain a uranium enrichment capability, and to develop toroidal plasma fusion reactors. Nuclear energy has been the largest government R&D expenditure throughout the 1960's and 1970's. But these expenditures have been only a small fraction of the programs in other countries like the U.S., U.K., and France. In 1971, 67 billion yen were spent on nuclear energy R&D, in 1972, 69 billion yen. Most of this was spent in the government research institutes, especially Japan Atomic Energy Research Institute (JAERI) and the Power Reactor and Nuclear Fuel Development Corp. (PNC).

Table 32

PURCHASE OF ATOMIC ENERGY TECHNOLOGY BY JAPAN

Items	Countries	Numbers	Applicants	Prices (thousands or yen)	Remarks
REACTOR	U.S.A.	15	8	6 073 033	1959, June
	U.K.	7	4	2 087 428	
	F.R. Germany	1	1	48 000	1971, Dec
	Sub-total	23	10	8 208 461	(30 401 702)
FUEL	U.S.A.	5	4	(2 636 914)	
				711 967	1963, Oct
	Sub total	5	4	711,967	--1970, Dec.
REPROCESSING	U.S.A.	2	1	40 523	1963, Dec
	U.K	2	2	145 021	
	France	4	2	1 317 285	– 1968, Oct.
	Sub-total	8	3	1 502 829	(5 566 032)
USES OF RADIATION	U.S.A.	5	5	81 540	1961, Nov.
	France	1	1	15 881	
	F.R. Germany	1	1	—	
	Switzerland	1	1	—	--1971, Jan.
	Sub-total	8	8	97 421	(360 819)
OTHERS	U.S.A.	19	15	772 173	1961, Feb
	U.K.	2	2	80 200	
	Switzerland	1	1	24 000	–1971, Sept
	Sub-total	22	18	876 373	(3 245 825)
TOTAL	U.S.A.	46	—	7 679 236	(28 441 609)
	U.K.	11		2 312 649	(8 565 365)
	France	5		1 333 166	(4 937 651)
	F.R. Germany	2		48 000	(177 778)
	Switzerland	2		24 000	(88 889)
GRAND TOTAL		66		11 397 051	(42 211 292)

1. *All technical contracts or payments in this table last for periods more than one year.*
2. *Foreign exchange is counted on the basis of Yen 270 to the U.S. dollar, and the others at offical rates. Numbers in parenthesis are in U.S. dollars.*

SOURCE: K. Mori, "Present Scope and Specialties of Japanese Nuclear Industry," *Nuclear Engineering International*, July 1973, p. 549. Reproduced by permission.

Expenditures at these research institutes grew from 51 billion yen in 1971 to 63 billion yen in 1973.[2]

In 1971, 12.8 billion yen was spent on R&D by industry, 11.6 billion self-financed. This 11.6 billion yen constituted 17% of sales, making this far and away the most R&D intensive industry.[3] In 1972, perhaps in part due to the economic crisis, R&D expenditures by industry fell below 10 billion yen.

Earlier expenditures were at a far more modest level, only 7.9 billion yen in 1962, 10.6 billion yen in 1964, and 15.3 billion yen in 1967 in the government sector.[4] This was a period of learning and preparation for the larger programs of the 1970's. Through the present time Japanese achievements have been modest and this is reflected in the U.S. patent statistics in the area of nuclear energy. The Japanese have obtained only 15 of the 2170 patents awarded between 1963 and 1972 in the area of nuclear fission reactor systems and components, tenth place among foreign nations.[5]

Presently all new reactors being built in Japan are either GE boiling water (BWR) or Westinghouse pressurized water (PWR) light water reactors which require 3% enriched uranium as the fuel element. Hitachi and Toshiba both have GE licenses, and Mitsubishi has a Westinghouse license. The first power reactor built in Japan was a 160 MW (electrical) British GE natural uranium gas-cooled reactor (AGR). This reactor did not prove satisfactory, but the experience with it has helped in the development of domestic gas-cooled reactors to be discussed below.

The Japanese obtained the design for their spent fuel reprocessing plant from the French firm Saintes-Gobain Techniques Nouvelles.[6] In other parts of the nuclear fuel cycle the Japanese have obtained U.S. technology from GE and Westinghouse. Only in the area of uranium enrichment have the Japanese had to develop their own independent capabilities.

Japanese efforts to develop a uranium enrichment capability have been directed at both gaseous diffusion and centrifuge techniques. It is only since the late 1960's that these efforts have had priority status. The goal is to have a competitive commercial plant by 1985.

The centrifuge process seems to be favored with the claim being made that this process has reached technical feasibility, with more study needed on economic feasibility.[7] Japanese ability to produce the needed carbon fibers for the centrifuges is clear. Toyo Rayon, among others, is a leading producer of high grade carbon fibers. Mitsubishi has also recently announced a membrane breakthrough that gives Japan the capability of building a gaseous diffusion plant.[8] Mitsubishi has completed a trial plant design using the new membrane. The Japanese therefore have developed technology in this area, technology not available on license because of its weapons applications.

The Japanese presently have three separate efforts for the development of new reactors. One of these is the advanced thermal reactor (ATR), a heavy-water-moderated, boiling-light-water-cooled reactor, that will be capable of using natural uranium fuel slightly enriched with plutonium. The prototype 165 MW ATR "Fugen" is scheduled to become critical in 1975, and will use slightly enriched uranium with plutonium addition.[9] The ATR is similar to the British Steam Generating Heavy Water Reactor.[10] The ATR program makes use of much of the experience gained from U.S. LWR's. It is meant to serve as an interim reactor to reduce dependence on foreign enriched uranium until the fast breeder reactor program bears fruit. PNC directs the effort which involves extensive industrial participation. Four nuclear energy groups (Hitachi, Toshiba, Mitsubishi, and Fuji) have cooperated and shared the work. It would be interesting to see if lack of coordination has slowed this effort and the other nuclear reactor efforts as it has in similar situations in the space program. Some people have indicated this is so.[11] In any case with the present shortage of heavy water, the slow pace, and the high capital cost of the ATR, the rationale for continuing beyond the prototype stage may be weak.[12] Present plans do call for a 645 MW thermal ATR to be built by 1980.

The main effort is being concentrated on liquid metal fast breeder reactors (LMFBR). The first experimental LMFBR, "Joyo," fueled with a mixed oxide of plutonium and uranium, cooled with liquid sodium, and rated at 100 MW thermal, was scheduled to become critical in 1974, but 1975 may be more likely. There has been some French help

in evaluating the design of this reactor.[13] PNC again coordinates the program, and the four groups participating in the ATR program also participate in this effort.

A prototype LMFBR, "Monju," rated at 300 MW electrical, was scheduled to begin construction in 1974, and become critical around 1978. PMC, together with five industrial groups (Sumitomo plus the four above), developed the design. Overall, the Japanese LMFBR effort clearly trails those elsewhere in the world (France, U.K., U.S.), and despite massive funding by Japanese standards, the effort is not funded well by international standards. (The U.S. spent $357.3 million on LMFBR in FY74, and will spend $473 million in FY75).[14] Results will therefore lag behind those elsewhere.

Along more independent lines, JAERI and MITI are sponsoring research on high temperature gas cooled reactors (HTR).[15] This development grows out of experience with the British AGR. The Fuji group is the main industrial participant. JAERI is to construct a 50 MW (th) very high temperature gas cooled reactor (VTR) by the end of the 1970's. The outlet coolant gas will have a 1000°C temperature, and will be put to multiple industrial uses. MITI is sponsoring a big project to develop one of these applications, iron and steel making. This project started in 1973 with a six year budget of 7.8 billion yen. It aims at producing "heat resistant materials, heat exchangers, reducing gas production equipment, direct iron ore reducing systems, and studies on the whole system analysis."[16] This development is unique to Japan at the present time.

In the area of toroidal plasma fusion reactors, the Japanese have achieved some important results, and are committed to a major research effort in the last half of the 1970's. JAERI's Thermonuclear Fusion Lab had a budget of 409 million yen for R&D in 1972 (excluding staff and administration costs), and 273 million yen was spent building JFT-2 (JAERI Fusion Torus-2), their "fat" tokomak, between 1970 and 1972.[17] There were about 30 scientists on the staff in 1972. The JFT-2 machine has attained the world's best confinement time, 25 milliseconds, at an electron temperature of 7 million°C.[18] During the second stage of the program, from 1975 to 1979, a larger toroidal

machine will be built, with the aim of fulfilling the Lawson criterion. The level of funding will be about 80 billion yen for the 5-year period. This will be the largest single project ever undertaken in Japan, and the level of funding compares favorably with U.S. efforts. It will be worth monitoring. One Japanese source felt that managing such a large project will be a severe test of Japanese management capabilities.[19]

The next generation torus will use ordinary ferromagnets. There is presently some work on using superconducting magnets to confine a high temperature plasma.[20] This is a joint effort of Tokyo and Nagoya Universities. Superconducting magnets probably will be needed in the later stages of plasma fusion research, and other Japanese efforts to develop superconducting technology will be useful at that time.

Japanese work on laser fusion is at a very low level of funding. One group at the Institute of Laser Engineering, Osaka University, is involved.[21] They are presently developing a Nd glass laser with a 2 nano-second pulse width, 250 joule output, in cooperation with Japan Electron Optics Laboratory Co. (JEOL). The Science and Technology Agency (STA) supports the project. The lack of development of high energy pulsed lasers in Japan will probably keep the effort at a low level for some time.

NUCLEAR ENERGY

Footnotes

1. *R&D in Japan*, 1973, Table 4, p. 23.

2. *Ibid.*, and *Budget in Brief, 1974*, p. 46. Note: of the 67 billion yen budgeted for atomic energy in 1974, 10.1 billion yen is for nuclear reactor safety, a 95.6% increase over 1973. This is a reflection of growing concern about this in Japan.

3. Mori, K., *Nuclear Engineering International*, "Present Scope and Specialties of Japanese Nuclear Industry," July 1973, p. 549.

4. OECD, 1967, p. 196; and V. Gilinsky and P. Langer, *The Japanese Civilian Nuclear Program*, The Rand Corporation, RM-5366-PR, August 1967, p. 42. (Rate of 360 yen = $1 used to convert back to yen for 1967 figure.)

5. *Technology Assessment and Forecast*, December 1973, U.S. Patent Office, p. 221.

6. Gilinsky and Langer, *op. cit.*, p. 25.

7. Kiyonari, S., *Nuclear Engineering International*, "Activities of PNC," July 1973, p. 558.

8. *Technocrat*, "Epoch-making Membrane Developed for Diffusion Process," June 1974, p. 9.

9. Kiyonari, S., *op. cit.*, p. 557.

10. Gilinsky and Langer, *op. cit.*, p. 35.

11. Private communication, Dr. Ohkawa, General Dynamics.

12. Private communication, Professor M. Plesset.

13. Kiyonari, S., *op. cit.*, p, 556.

14. Hafemeister, D., *American Journal of Physics*, "Science and Society Test for Scientists: The Energy Crisis," Vol. 42, August 1974, p. 640.

15. Murata, H., *Nuclear Energy International*, "Research Activities in JAERI," July 1973, p. 546. Also: "FAPIG and its Activities in the Nuclear Field," T. Kasaba, p. 570-71.

16. *Ibid.*, p. 546.

17. "Annual Report of JAERI Thermonuclear Fusion Lab," October 1972, p. 65.

18. "Fusion Reactor Development Schedule," *Technocrat*, February 1974, p. 8.

19. Private communication, Dr. Ohkawa, General Dynamics.

20. Brandt, R. G., "Superconducting Technology in Japan," ONR-28, June 1971, p. 10.

21. *Technocrat*, "Thermonuclear Fusion Reaction by Heating Plasma with a Laser," July 1974, p. 6.

2. Large Scale Applications of Superconductivity to Energy Technology

a. Introduction. The Japanese have shown considerable interest in the area of large scale applications of superconductivity over the last ten years.

Here we will be concerned basically with three efforts. These are in the area of magnetohydrodynamic (MHD) power generation, super-conducting generators, both dc and ac and cryogenic power transmission. Research in these areas has been carried on mainly by the government research institutes, especially ETL, and industrial laboratories.

In the universities there is broad research effort at a more basic level. All the traditional areas of low temperature physics are covered and the quality of the work is very good by international standards.[1] Tohoku University in Sendai and its associated Research Institute on Iron, Steel, and Other Metals, and on Electrical Communications, are especially strong in the area of basic research.

The progress of the Japanese has been remarkable. Until 1961 research activities on superconductivity had been at a very low level in Japan. The number of helium liquefiers was less than ten, and these had been entirely imported from abroad. Largely spurred by the discovery of high field superconductors with their obvious applications to magnets, several large Japanese companies became involved in the effort. Between 1963 and 1967 Japanese liquefiers were developed, and since 1967 only Japanese models have been sold, and many exported.

Several companies started the development of superconducting materials in the early 1960's, and today there are hosts of proprietary Japanese materials available. Mitsubishi, for example, has developed a material called Tanalloy.[2] It consists of an alloy of Ti-Nb-Ta and has been used in d.c. magnets of up to 75 kG (kilogauss).

Very recently Furukawa Electric has mass-produced the world's first superconducting magnet wire made of V_3Ga.[3] This is among the highest field superconductors known, and development of the wire is a major accomplishment.

This tendency of the large industrial research laboratories to have a strong in-house capability to produce the materials used in their research is a characteristic of these labs. Similar situations can be found in such areas as optical fibers and semiconductor materials.

The focus of the large-scale efforts has been the development of more efficient systems for generating and transmitting electric power. Much of the work is still in very early stages of development (pre-prototype for the most part), but it has been of high caliber and there is promise of future application.

b. MHD Power Generation. The major focus in the area of large-scale applications of superconductivity during the period 1966-1972 was the "big project" supported by The Ministry of International Trade and Industry (MITI) on MHD power generation. ETL was the coordinator of this project, and the main contractors were Hitachi, Mitsubishi Electric, Toshiba Electric, the Japan Oxygen Company, and Toyoda Machine Works, Ltd. The total government budget during the seven-year period was about five billion yen ($16.7 million).[4]

Work on this project proceeded in three phases. The first phase utilized a 23-kG superconducting saddle-shaped magnet. The superconductor was manufactured by AVCO in the U.S., but the magnet was constructed at ETL. A maximum of 25 W was produced in a 5-minute test run of the combustion system.

During the second phase a larger saddle-shaped superconducting magnet of wholly Japanese manufacture was developed. The superconductor was fully stabilized Nb-Zr-Ti composite wire produced by Hitachi. Mitsubishi Electric did much of the magnet construction. The maximum field was 45 kG and the stored energy was 4.5 MJ (megajoules). Maximum MHD power was 200 kw and emphasis was given to the combined operation of combustion system and superconducting magnet.

During phase three, which started in 1970, a superconducting magnet of the race-track type with a uniform field space at room temperature of 10 x 20 x 120 cm was constructed. This is the largest magnet of its kind in the world, with a central field of 50 kG and a

stored energy of 70 MJ. A successful test of the magnet was completed in 1973 and presently work is under way on combined operation with a combustion system to produce 1 MW output for a 5-minute running period.

For 1973-1975, the budget for this project will be 900 million yen per year ($3 million).[5] A prototype MHD generator has been proposed, but government approval has not been obtained.

As Table 33 shows, MHD has been an area of decreasing patent activity in the U.S. During the period 1970-1972 Japan received 7% of all U.S. patents in this area, but the decreased patent activity is an indicator of decreased interest in this sort of power generation. The experience gained by the Japanese in this project, however, will be useful for those that will follow in other areas.

c. Superconducting Generators.

(1) Superconducting dc homopolar generators. Toshiba Electric began research and development on a dc homopolar generator in 1967.[6] Successful operation was achieved in 1970. The basic design was a room-temperature rotor rotating in a 40 KG axial magnetic field produced by a superconducting magnet. Output at 3000 rpm was 10 kv (10V, 1000A).

The next phase of research was sponsored by the Japan Society for Promotion of Machine Industry. Furukawa Electric and several other companies were involved in addition to Toshiba. The total budget for 1971-1973 was 180 million yen ($600,000). The superconducting magnet of this machine is a 40 kG pancake magnet with stored energy of 26 MJ. Output is 3 MW (150V, 20kA). It will be used at Furukawa Nikko Works for a six-month trial period as a power source for a copper electrolyzing plant. This generator is viewed as a test bed by the entire electrolytic refining industry, which uses large amounts of dc power.

This effort compares favorably with those in other nations and it has been entirely indigenous.

(2) Superconducting ac generators. Work on superconducting ac generators is relatively undeveloped in Japan.[7] Hitachi had developed a prototype 1 kw ac generator by 1970. But that program was dropped when it was found the design did not extrapolate to larger power capacities.

Table 33

MAGNETO-HYDRODYNAMIC GENERATORS

Dynamo-electric apparatus for generating electrical power by the passage of a conducting fluid (either gas or liquid) through a magnetic field. The fluid is driven through the magnetic field at high velocity and electrical power is obtained from electrodes which are in contact with the fluid.

DISTRIBUTION OF U.S. PATENTS IN AREA OF INTEREST

FOREIGN	1963	64	65	66	67	68	69	70	71	72	Total 63-72
FRANCE	1	1		4	5	10	18	8	6	4	57
GERMANY	1	3	2	1	9	6	3	2	4	1	32
UNITED KINGDOM		1	2	1	3	5	9	4	1		26
SWITZERLAND		2	1	3	3	3	5				17
JAPAN				1	1	2		1	4		9
SWEDEN	1			1			1				3
CANADA	1						1				2
NETHERLANDS										1	1
DENMARK										1	1
ICELAND		1									1
AUSTRIA							1				1
NEW ZEALAND					1						1
ITALY								1			1
TOTAL FOREIGN	4	8	5	11	22	26	38	16	15	7	152
UNITED STATES	17	36	51	50	38	21	32	18	10	10	283
TOTAL	21	44	56	61	60	47	70	34	25	17	435

ACTIVITY INDICES

Average % Foreign	49 %
Projected Average % Foreign	75 %
Minimum % U.S. Owned of Foreign	5.9%
Average % Growth	4.1%
Average % Assigned to U.S. Govt.	13 %

More recently Fuji Electric has constructed a 30 kw synchronous generator with an outer stationary superconducting field of 4 poles, and an inner rotating armature. They are presently planning to develop an ac generator with an inner rotating field.

d. Cryogenic Power Transmission. High capacity and efficiency power transmission systems are obviously important in making use of energy resources. Since 1964 the Central Research Laboratory of the Electric Power Industry has been involved in superconducting power transmission. Their work has been on design and cost estimation, largely of dc transmission lines. ETL has been conducting experimental studies on ac losses and the economy of such systems.[8]

Furukawa Electric has been the leader in developing model superconducting cables. They have also worked on cryoresistive cable using liquid nitrogen as the coolant.

A big project has been proposed for the development of superconducting transmission systems, and is expected to start in 1975. Total budget amounts to 20 billion yen ($67 million) for the first period of 8 or 9 years. This will be a major spur to the development of the superconducting technology in the heavy electric industry.[9]

SUPERCONDUCTIVITY

Footnotes

1. R. G. Brandt, "Superconducting Technology in Japan," ONR-28, June 1971, p. 1.

2. *Ibid.*, p. 10.

3. "World's First Mass-Production of Superconductive Magnet Wire Made of V_3Ga Successful," *Technocrat*, July 1974, p. 9.

4. K. Yasukochi and T. Ogasawara, "Programs on Large-Scale Applications of Superconductivity in Japan," in S. Foster and B. Schwarts (eds.), *Superconducting Machines and Devices: Large Systems Applications*, 1974, pp. 623-624.

5. *Ibid.*, p. 624.

6. *Ibid.*

7. Yasukochi and Ogasawara, *op. cit.*, p. 624.

8. *Ibid.*, p. 625.

9. *Ibid.* More recently "Superconductive Electric Power Transmission System," *Technocrat*, June 1974, p. 27, reports a planned budget of 16.5 billion yen.

I. SHIPBUILDING AND OCEAN MINING

1. Development before 1945

Before discussing the post-war developments in naval architecture and ship construction technology we should recall the advanced state that the shipbuilding industry had reached in Japan before and during World War II.[1]

The Japanese Imperial Navy enjoyed a high priority in national efforts. New shipbuilding technologies were learned and adopted as soon as they were developed anywhere in the world. The University of Tokyo had the oldest department of naval architecture in Japan, established in 1883, and there were also departments in the imperial universities at Kyushu and Osaka, all helping to provide the personnel needed for the national effort.

As a result of this intense national effort, technical levels in various areas of naval architecture and marine engineering, including hydrodynamics and structural design, had attained approximate parity with those in the West. This is indicated by the design and construction of a number of warships. Among these were the *Yamato* and the *Musashi*, each displacing 69,000 gross tons, which were built just before the outbreak of World War II and were considered the most powerful battleships at that time.[2]

During the war the Japanese fell sharply behind in shipbuilding technology. In the United States new prefabrication and welding techniques were developed under pressure and applied in a crash program to produce Liberty Ships. When the war ended with many Japanese shipyards destroyed, the Japanese shipbuilding technology was far behind that of the U.S. in the area of welding technology, but in other areas technical levels were almost as advanced as those of the U.S.[3]

Thus when the Japanese set out to reconstruct their shipbuilding industry after the war they had experience, tradition, know-how, and manpower to call upon.

2. Acquisition of Technology, 1945-1959

A high priority was early given to the acquisition of welding technologies from the west. This technology appeared on MITI's first

shopping list in 1950, *First Announcement of Desirable Technologies*.[4] In the early 1950's the Japanese shipyards set out to assimilate these techniques and they did so with particular thoroughness. The submerged arc welding process was introduced, and concerted efforts were made to overcome the problem of cold brittleness of welded hulls. Shipyard layouts were realigned to exploit every advantage of the new system of arc welded block construction.

The technologies that were introduced came from the U.S. and Western Europe, in particular Sweden and West Germany.[5]

3. Japanese Innovation in the 1950's

By the late 1950's Japanese-developed welding technologies began to appear. An example is the development of large-diameter welding electrodes for horizontal fillet welding (E6020 type).[6] At this time Japan was already building 22% of the world's new merchant ships.

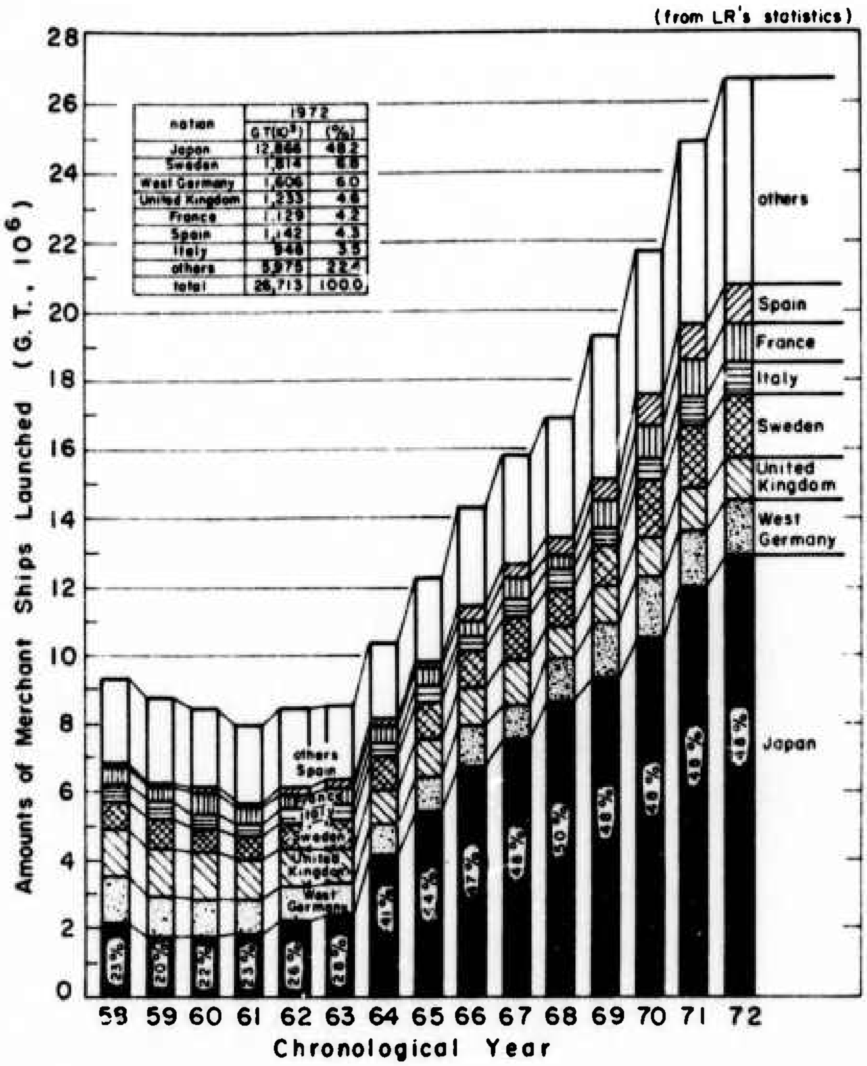
The system of building ships by assembling welded modules, the so-called "block system," had been established. And Japan had reached parity with the world in shipbuilding technology.

In the area of hull design Professor Takao Inui of the University of Tokyo was among the world's leaders. His work on the bulbous bow, a low-drag hull shape, continued and systematized the work of Weinblum and Wigly, who had been the originators of the idea in the 1930's.[7]

4. Development in the 1960's

During the 1960's Japanese ship construction technology became the most advanced in the world as far as the construction of commercial ships, especially large tankers, was concerned.

This was a time of rapid growth for shipbuilding everywhere (see Figure 11). But the Japanese led the way in the production of the giant tankers. They were able to build these ships faster and cheaper than their competition in Europe. Between 1963 and 1972 their production increased more than five-fold. To build these new ships at the speed and price at which they were offered required great organization and improved technology.



SOURCE: Koichi Masabuchi and Kiyoshi Terai, "Assessment of the Japanese Shipbuilding Industry," *Marine Technology*, Vol. 11, No. 3, July 1974, p. 250. Reproduced by permission of the Society of Naval Architects and Marine Engineers.

Fig. 11--Merchant ships launched in the world

As the size of the Japanese shipbuilding industry grew, it became possible to specialize production systems for certain types of classes of ships, unlike the situation during the 1950's when ships were individually designed for each customer. This was a major factor in cutting both time and costs in construction.

A major factor in reducing overall costs was the reduction in cost in fabricating the basic construction unit, the "block" or "module," a panel structure of steel plates.[8] Conveyor systems were introduced in fabrication shops. Statistical quality control was applied in ship fabrication and numerically controlled flame cutting was introduced.

There were also many advances in welding technology.[9] Electrodes especially suited for down-band vertical welding were developed. They were useful for improving the productivity of fabricating panel structures. Semiautomatic gravity welding was developed. It uses a large-diameter, long electrode which is placed on a fixture so that a fillet weld is made automatically as the electrode melts and the arc advances. The process does not require skilled labor, and one worker can handle several units.

As noted above, submerged-arc welding was introduced to Japan in the early 1950's. The Japanese during the 1960's developed the one-side submerged arc welding process.[10] This process is extremely useful in butt welding large plates, because the plates do not have to be turned over to be welded on both sides.

Throughout this period the Japanese continued to monitor developments elsewhere, and there was an increase in licensing agreements with foreign firms. One example is the vertical automatic welding processes, including electroslag and electrogas processes, introduced from the Soviet Union, and still widely used for welding butt joints between large assemblies.[11]

Between 1950 and 1964 at the outset of the boom period there were a total of 8 licensing agreements of type A contracted by Japanese shipbuilding firms and thirteen of type B. However, in 1964 only 1.9% of total sales consisted of sales of products with license-related technology.[12] Thus what we have here is a willingness to borrow from abroad, but certainly no dependence on foreign technology.

The lack of export of Japanese technology abroad, only 3 licenses being contracted during the period 1950-1964, may be accounted for by the fact the Japanese innovations during this period could be fairly easily duplicated abroad. Perhaps also the slowness of Western shipbuilders to develop more efficient methods may have been due to greater restraints of both labor practices and equipment in place in the West.

In ship design the Japanese continued to be leaders. Some of the hulls of the first large tankers showed a great deal less than their estimated strength. They had a propensity for buckling and cracking under certain pressures, but structural analysis carried out by computer has helped to strengthen succeeding generations of tankers.[13]

A great deal of automation also went into the tankers.[14] Unmanned engine rooms, with self-driving devices, electric eyes, and instantly triggered alarms became common on the supertankers, allowing sharp decreases in the size of the crew.

The cost-saving techniques that have been developed for the building and operation of the tankers have not been greeted with universal acclaim. Noel Mostert in a recent *New Yorker* series has criticized such practices as using only single propeller and single rudder systems. The *Globtek London* and *Globtek Tokyo*, each 477,000 DWT, are propelled by a single giant propeller produced by Kobe Steel. We are not in a position to judge such designs or whether Japanese practices differ from those of her European rivals.

5. Developments in the 1970's

The specialization of shipyards has continued over the past few years.[16] Massive building dock and erection systems have been developed at several new shipyards that allow a more even time distribution of labor. Basically they consist in having more than one ship on the dock at the same time.

Productivity in ship construction continues to increase. For example, Mitsui Shipbuilding has developed the ROTAS (rotating and sliding) system for transferring huge D-type modules from the sheltered shops on the ground where they are constructed to the building dock

without the use of cranes.[17] The D-type module, a wing cargo part of a tanker or ore/oil carrier, weighs between 800 and 1400 tons and measures 12,000 to 16,000 cubic meters.

Further improvements have been made in welding technology.[18] For example, one-sided submerged welding systems for joining curved plates have been developed. Some of the most advanced automatic welding machines are now controlled by computers.

In all areas of naval architecture the Japanese are now among the leaders in the world.[19] In the universities there are several large departments of naval architecture and marine engineering. All of these departments have outstanding faculties and large numbers of students. Approximately 200 naval architects graduate each year, and most stay in marine professions.

Furthermore, important work is also done at the National Research Institutes, such as the one at the Defense Academy in Yokosuka. Contact between the universities and the industry and within the industry itself is close and cooperation is extensive.[20] The entire program is very well funded. The Japan Shipbuilding Research Association coordinates the research efforts of shipbuilding companies, government laboratories, and universities through committees on various research projects.

6. LNG Carriers

One area of ship construction where the Japanese trail their European and American competition is in the construction of LNG carriers. They were not the innovators in this area but are now working hard to develop the technology through licensing with foreign companies and/or developing their own designs.[21] An important current welding problem is how to successfully weld 9% nickel steel alloys and heavy aluminum plates to be used for joining tankages of LNG carriers. This technology has been developed elsewhere, but new advances may be made. For example, some Japanese shipbuilding engineers are working on the use of electron-beam welding for joining heavy aluminum sections.[22]

There are two basic reasons for the Japanese lag in developing LNG carrier technology. The first is that this technology is not in the usual realm of marine technology. We are really dealing with cryogenic systems on a large scale. This has been an area of technology in which the Japanese trail. They have not gained experience with cryogenics in their space program since until recently they only dealt with small solid fuel rockets. In the U.S. the technique for liquifying natural gas was perfected as part of our space program, in which large liquid fuel rockets were developed.[23]

The second reason for the lack of development of LNG technology in Japan was the lack of development of the gas industry in Japan. Until recently gas was not an important source of energy in Japan. In Europe, where the technology for LNG carriers was further developed in the 1960's, gas was an important source of energy, and for the most part it had to be imported from North Africa. The United Kingdom, France, Sweden, and Norway have thus led the way in building these tankers by perfecting the techniques for handling the expensive aluminum and nickel alloys that are presently used for LNG tanks. Indeed several U.S. shipbuilders, including Newport News Shipyard and General Dynamics, have signed licensing agreements with West European firms as they undertake the construction of LNG carriers.[24]

Japanese firms have signed similar agreements over recent years with various West European LNG design organizations. Kawasaki, for example, will start delivering Moss-Rosenberg design self-supporting spherical aluminum tank LNG carriers in 1977, each with a capacity of 128,600 cubic meters.[25] It is worth noting that the first LNG ship of this design, the *Venator*, with a capacity of 29,000 cubic meters, has only this year been delivered by Moss Verft to a Norwegian shipping firm.[26] Thus the Japanese appear confident that they will be able to quickly master this new technology, and furthermore scale it to the size appropriate to their massive shipyards.

One should further note here that General Dynamics in Quincy, Massachusetts, is also going through a program similar to that at Kawasaki.[27] They are also using the Moss-Rosenberg technology,

together with a large amount of their own research and development, in setting out to build seven LNG carriers with capacities of 125,000 cubic meters each. It would be interesting to compare the way in which these firms have gone about developing their capabilities in this area. The General Dynamics design, the analytical work behind it, and the work on the properties of the aluminum alloy to be used are apparently very well documented.[28]

7. Advanced Propulsion Systems

The Japanese have brought conventional steam and diesel marine propulsion systems to a high level of development. This development has involved licensing agreements with such firms as Babcock and Wilcox and Sulzer Brothers of Switzerland. But the Japanese industry does have independent advanced capabilities in this area now.

In the area of more advanced propulsion systems, which have chiefly been of naval and not commercial interest thus far, the Japanese trail, although they do have potential capabilities.

The Japanese have completed the construction of the *Mutsu*, their first atomic-powered ship. The *Mutsu's* power plant only generates 10,000 horsepower, far less than the new systems that may be used on the big tankers which will generate 100,000 to 120,000 horsepower.[29] Development has been slowed considerably by the strong fear of radiation leakage on the part of the Japanese population. The *Mutsu* periodically has difficulty getting back into port. The large companies which are presently involved in the transfer of U.S. reactor know-how to Japan will have the capability of developing nuclear propulsion systems. But they trail their European and American competitors by a large margin. Current plans are for design work on the second Japanese atomic ship to begin in 1975, with completion of construction scheduled in 1985.[30] Current European and American plans are far advanced of this schedule. Some Japanese companies are seeking U.S. naval reactor technology.[31]

The Japanese also trail in the development of marine gas turbine propulsion systems. This has mainly been of interest to the U.S. and U.K. navies up to this time.[32] G.E., Rolls-Royce, and Sulzer

Brothers are presently involved. But in estimating Japanese capabilities in this area one should keep in mind the fact that Hitachi has been selling large gas turbines to the U.S. for several years.[33] Thus the know-how may exist for adapting this technology to marine use, if it proves economically viable.

8. Mining Manganese Nodules

In developing the technology for mining manganese nodules from the deep ocean bed the Japanese have taken and will take an active part.

Sumitomo is the Japanese leader in this area. They, in cooperation with the American designer, John L. Mero, have been working on developing the continuous line bucket method for mining nodules. Their initial work using a single boat was not successful, but plans are under way for a two-boat system which will soon be put to trial.[34]

Other Japanese companies have joined a venture with the Tenneco subsidiary, Deepsea Ventures, Inc., a world leader in the hydraulic system for mining nodules and in processing the nodules. These firms are C. Itoh & Co., Kanematsu Co., and Nichimen Co. They will provide much of the hardware involved, building to Deepsea Ventures' designs.[35]

This is certainly a most important area, and should be further explored.

SHIPBUILDING

Footnotes

1. K. Masubuchi and K. Terai, "Assessment of the Japanese Shipbuilding industry," *Marine Technology*, July 1974, pp. 249-259, is the source of much of the material below.

2. *Ibid.*, p. 255.

3. *Ibid.*

4. Tsurumi thesis, p. 135.

5. "Modern Evolution of Science and Technology in Japan," statement by K. Kaneshige before *Panel on Science and Technology, 8th Meeting*, January 24, 1967, Committee on Science and Astronautics, U.S. House of Representatives, p. 36.

6. Masubuchi and Terai, *op. cit.*, p. 255.

7. Private communication (Professor T. Wu, Cal Tech).

8. Masubuchi and Terai, *op. cit.*, p. 255.

9. *Ibid.*

10. *Ibid.*

11. *Ibid.*

12. Tsurumi thesis, p. 240. These figures appear a bit low. It may be that related technology was listed under other industries.

13. Noel Mostert, "Supertankers," *New Yorker*, May 13, 1974, pp. 66, 71.

14. *Ibid.*, p. 84.

15. *Ibid.*, pp. 72-84.

16. Masubuchi and Terai, *op. cit.*, p. 257.

17. *Ibid.*

18. *Ibid.*

19. Private communication (Professor T. Wu, Cal Tech).

20. Masubuchi and Terai, *op. cit.*, p. 259.

21. *Ibid.*, p. 254.

22. *Ibid.*, p. 257.

23. S. Sivewright, "LNG - Cargo for the 1970's," *New Scientist*, June 15, 1972, p. 612.

24. "Buildup for the Big Ones," *Marine Engineering/Log*, March 1974, pp. 43, 44.

25. Kawasaki Advertisement, *Marine Engineering/Log*, June 1974, p. 59.

26. "Moss Verft Delivers its First Spherical Aluminum Tank LNG Carrier," *Marine Engineering/Log*, March 1974, p. 50.

27. "Buildup for the Big Ones," *Marine Engineering/Log*, March 1974, p. 43.

28. *Ibid.*, pp. 42-43.

29. Private communication.

30. "Second Atomic Ship Planned," *Technocrat*, February 1974, p. 22.

31. Private communication.

32. "Conference Reveals New Marine Gas Turbines Under Development, *Marine Engineering/Log*, May 1974, p. 52.

33. Hitachi Annual Report, 1972.

34. Private communication.

35. *Ibid.*

IV. CONCLUSIONS

Japan's scientific and technological capabilities are today rapidly developing. The increased acquisition of U.S. patents, the growing number of international cross-licensing agreements, Japan's increased participation in international joint research efforts, and the growing number of Japanese scientific and technological achievements are all indicative of this trend.

This growing strength is the result of an intensified effort in Japan to promote domestic technology. The effort has for the most part been concentrated in the major corporations of the industrial sector and the research institutions associated with various government agencies and ministries, which work closely with the large industrial laboratories. Basic research, largely the province of the universities, has been very poorly funded. The focus has been on developing technology with a strong commercial potential. (Research related to military, space and other national interest applications has played a very small role in Japan's efforts.) The industrial effort is directed toward a relatively small number of industries: electrical machinery and electronics, autos, chemicals, iron and steel, and ships account for most of Japan's industrial R&D expenditure.

Much of the basic technology upon which Japanese efforts build has been imported from abroad by licensing. In the days when foreign investment in all sectors was tightly controlled by the Ministry of International Trade and Industry (MITI), prior to 1968, the Japanese systematically went about acquiring the technology upon which to develop their economy. The United States was the source of almost 60% of this technology. In fields from petro-chemicals to computers, technical assistance agreements were concluded to introduce advanced technologies. These agreements typically called for royalties of less than 5% of sales, and constituted a bargain for Japanese industry. For example, Japanese industry acquired U.S. light water reactor technology for only 6 billion yen ($20 million), a very small fraction of the original development cost. Licensing thus allowed the rapid

development of technological capabilities at minimum expenditure. The government--and especially MITI--played a key role in keeping down the cost of imported technology, and in gaining access to foreign technology for Japanese firms.

In recent years with Japan's accelerating movement toward broad technological parity with the West, the character of imported technology has been changing while the quantity has continued to grow. There has been a movement away from agreements involving technical assistance toward pure patent licensing. Cross-licensing has also increased, and related Japanese companies have taken part in joint-research efforts with U.S. companies. There have been a few well-publicized exports in such areas as urea fertilizer and automotive engines, cases where the Japanese have been able to sell improved technology back to its source.

Japanese research efforts have largely moved forward in parallel with those of the United States. Even with the increased stress on developing domestic technology in Japan, and the corresponding increase in levels of expenditure on R&D, Japanese industry still has difficulty competing head-on with the giant American companies. For example, IBM's $730 million annual expenditure on R&D allows it to conduct research in very high risk basic research areas, such as crvogenic computers. No Japanese company can hope to emulate such an effort. Similarly, Bell and Corning Glass have been more successful in developing optical fibers than NEC and Nippon Sheet Glass with their comparatively limited means. High-temperature superconductors and high-energy pulsed lasers will be developed in the United States rather than in Japan.

Japanese companies instead specialize in developing and improving existing technology. While the cream may have been skimmed by the originator of the technology, there remain often many further applications or improvements to be made. To cite an example, the Japanese are not leaders in basic research on artificial intelligence or high-temperature superconducting materials, but they have developed some very interesting industrial robots and the commercial production of V_3Ga wire. They were not the originators of the electron microscope,

but they have become leaders in the development of this instrument. The same is true for the Tokomak concept for fusion reactors, welding technology for shipbuilding, and oxygen converters for iron and steel manufacturing.

The Japanese have done little pioneering on basic technology. They have had to be selective in choosing where to concentrate their R&D efforts, and high-risk pioneering research has been given low priority for the most part. This can cause problems for the Japanese, for there is always the danger of being leap frogged by developments elsewhere. Possible examples of this exist in the areas of fermentation technology and ship propulsion systems, areas where Japanese industry has reached high levels in the conventional technology.

Advanced technology may be increasingly expensive to license. With foreign investment largely decontrolled, foreign firms will be more insistent on joint ventures, and market restrictions on the licensee may become increasingly onerous. One detects a reluctance to license technology to Japan among some U.S. companies now that the Japanese are approaching technological parity. But any reluctance has yet to be reflected in the licensing statistics. (This question is worthy of further more systematic study.)

Today government policy in Japan is to concentrate on "knowledge intensive" areas, such as computers, fine chemicals, nuclear energy, semiconductors, and other industries where significant levels of R&D expenditure are required to compete on world markets. To implement this policy the government is increasing its R&D expenditures in many of these areas, hoping to make Japanese industry more competitive on world markets.

Japan's goal of restructuring its industry so as to decrease emphasis on the heavy industries, which consume large amounts of raw materials and where technology is relatively stable, and increase emphasis on "knowledge intensive" industries, which have a high value added and whose technology is rapidly changing, will challenge her present technological capabilities. Her greatest success in the past has largely been in areas of relatively stable technology. Pioneering breakthroughs have been rare and, indeed, have not been sought. Now

greater levels of R&D funds will have to be provided so as to pursue more basic research. There is especially room for improvement in funding university research, but industry could also bring its R&D expenditure as a percentage of sales more in line with U.S. figures.

Present economic difficulties make substantial real growth in R&D expenditures unlikely, and so the shift toward "knowledge intensive" industries is likely to be gradual for the next several years. The Japanese will still have to be thoughtful and selective in the research efforts they pursue. But they have long demonstrated their ability in product-oriented R&D of commercial importance, and such developments as Toyo Rayon's carbon fiber, Professor Masumoto's amorphous steel alloy, and Furukawa Electric's superconducting wire indicate they will be successful in product development in "knowledge intensive" areas, even if the majority of fundamental breakthroughs continue to come from abroad.

The government is responsible for the long-term, large-scale research efforts. The process of deciding on which areas to concentrate government R&D efforts involves the accommodation of the interests of the different government agencies and often of industry. The projects chosen aim at satisfying long-term national and industrial needs. Japanese transportation problems have led to the funding of research on road traffic control and magnetically levitated trains. Pollution problems have led to the funding of research on flue gas desulfurization and electric cars. The potential of the oceans to solve many resource problems is recognized with funding of research on desalination and remotely controlled, deep sea oil drilling rigs. New sources of energy and the efficient uses of present energy resources are also emphasized. All of these areas are of critical importance to Japan.

It is in the large-scale government projects that the greatest opportunity for government to government cooperation exists. MHD power generation, plasma fusion, road traffic control, cryogenic power transmission, magnetically levitated transportation, and solar energy are examples of areas where joint development efforts might be truly joint efforts, and where government involvement will be great both in the United States and in Japan.

APPENDIX

CLASSES OF THE U. S. PATENT CLASSIFICATION SYSTEM

Classes Included in Country and State Profiles

Listed below are the official titles of the classes of the U.S. patent classification system which are referred to by number in the country and state profiles included in this third report. For some titles brief explanations or examples, not part of the official title, have been included to aid the reader in comprehending the scope of the class. The titles are intended to be merely indicative and are not definitive of the technology included in the class.

Detailed definitions (a complete set comprising some 15 volumes of material) of every class and official subclass in the U.S. patent classification system are available and may be purchased, in total or in part, from the Patent Office. Inquiries or orders should be addressed to Commissioner of Patents, Washington, D. C. 20231.

Class	Title
2	Apparel
4	Baths, Closets, Sinks And Spittoons
5	Beds
8	Bleaching And Dyeing; Fluid Treatment And Chemical Modification Of Textiles And Fibers
9	Boats, Buoys And Aquatic Devices
10	Bolt, Nail, Nut, Rivet And Screw Making
12	Boot And Shoe Making
13	Electric Furnaces
15	Brushing, Scrubbing And General Cleaning
16	Miscellaneous Hardware (e.g., carpet-fasteners, door hangers, sash-weights, hinges, furniture-casters, etc.)
17	Butchering
19	Textiles, Fiber Preparation (mechanical manipulation of fibers to place them in condition for use)
21	Preserving, Disinfecting And Sterilizing
23	Chemistry (includes chemical analysis and preparation or physical treatment of inorganic compounds)
24	Buckles, Buttons, Clasps, Etc. (includes industrial fasteners)
26	Textiles, Cloth Finishing
28	Textiles, Manufacturing (miscellaneous, e.g., texturing, felting, warp preparing)
29	Metal Working (includes metal article assembling and disassembling with or without shaping, also the manufacture of a wide variety of specialized items)
30	Cutlery (includes industrial cutting tools, pruning saws, cold chisels, pipe cutters, etc.)
32	Dentistry
33	Geometrical Instruments (e.g., aerial bomb sights, gyroscopic compasses, etc.)

Class	Title
34	Drying And Gas Or Vapor Contact With Solids
35	Education
36	Boots, Shoes And Leggings
37	Excavating
38	Textiles, Ironing Or Smoothing
40	Card, Picture And Sign Exhibiting
42	Firearms
43	Fishing, Trapping And Vermin Destroying
44	Fuel And Igniting Devices (e.g., diesel fuel containing ignition promoters, matches)
46	Amusement Devices, Toys
47	Plant Husbandry
48	Gas, Heating And Illuminating
49	Movable Or Removable Closures (e.g., portable barricades, emergency exit doors, louvers)
51	Abrading
52	Static Structures, E.g., Buildings (including components)
53	Package Making (e.g., wrapping machines)
55	Gas Separation
56	Harvesters
57	Textiles, Spinning, Twisting And Twining
58	Horology
59	Chain, Staple And Horseshoe Making
60	Power Plants (e.g., jet engines, turbines)
61	Hydraulic And Earth Engineering
62	Refrigeration
63	Jewelry
64	Machine Elements, Shafting And Flexible Shaft Couplings
65	Glass Manufacturing
66	Textiles, Knitting
68	Textiles, Fluid Treating Apparatus
70	Locks
71	Chemistry, Fertilizers
72	Metal Deforming (e.g., rolling, extruding, drawing, etc.)
73	Measuring And Testing (other than electrical)
74	Machine Elements And Mechanisms (e.g., mechanical movements, gearing, linkage systems, cams)
75	Metallurgy (e.g., alloy production processes)
76	Metal Tools And Implements, Making
81	Tools (e.g., pliers, wrenches)
82	Turning (e.g., lathes)
83	Cutting (e.g., complete cutting systems including patterns and guides)
84	Music (musical instruments and accessories)
85	Driven, Headed, And Screw-Threaded Fastenings
89	Ordnance
90	Gear Cutting, Milling And Planing
91	Motors, Expansible Chamber Type (apparatus for converting energy of a pressurized fluid into mechanical work)
92	Expansible Chamber Devices (reciprocating or oscillating devices with no valve control of the motive fluid)
93	Paper Manufactures (e.g., machines for making bags, boxes, envelopes, etc.)

Class	Title
95	Photography (generally excludes lenses *per se*)
96	Photographic Chemistry, Processes And Materials
98	Ventilation
99	Foods And Beverages
100	Presses
101	Printing
102	Ammunition And Explosive Devices
104	Railways (e.g., railway systems, track layers, ski tows, monorails, cable cars)
105	Railway Rolling Stock
106	Compositions, Coating Or Plastic
108	Horizontally Supported Planar Surfaces (e.g., tables, industrial platforms)
110	Furnaces (generally solid fuel burning)
112	Sewing
113	Sheet-Metal Ware, Making (e.g., can making machines)
114	Ships
115	Marine Propulsion
116	Signals And Indicators (e.g., bells, sirens, flags, curb feelers)
117	Coating: Processes And Miscellaneous Products
118	Coating Apparatus
119	Animal Husbandry
122	Liquid Heaters And Vaporizers
123	Internal-Combustion Engines
124	Mechanical Guns And Projectors (non-explosive guns, e.g., under water spear guns; and projectors, e.g., bows, cross-bows)
125	Stone Working
126	Stoves And Furnaces (e.g., cooking stoves, steaming apparatus, fireplaces)
127	Sugar, Starch And Carbohydrates
128	Surgery
130	Threshing
131	Tobacco
132	Toilet (personal care articles, e.g., combs, manicure tools)
134	Cleaning And Liquid Contact With Solids
135	Tents, Canopies, Umbrellas And Canes
136	Batteries (including thermoelectric generators)
137	Fluid Handling (including plumbing and valve systems)
138	Pipes And Tubular Conduits
139	Textiles, Weaving
140	Wireworking
141	Fluent Material Handling, With Receiver Or Receiver Coacting Means
144	Woodworking
148	Metal Treatment (processes for treating solid metal to change its physical or chemical properties)
149	Explosive And Thermic Compositions Or Charges
150	Cloth, Leather And Rubber Receptacles
151	Nut and Bolt Locks
152	Resilient Tires And Wheels

Class	Title
156	Adhesive Bonding And Miscellaneous Chemical Manufacture (includes articles such as simulated wood paneling)
159	Concentrating Evaporators
160	Closures, Partitions And Panels, Flexible And Portable
161	Stock Material And Miscellaneous Articles (primarily webs, sheets, rods and fibers)
162	Paper Making And Fiber Liberation
164	Metal Founding
165	Heat Exchange
166	Wells
169	Fire-Extinguishers
171	Unearthing Plants Or Buried Objects
172	Earth Working
173	Tool Driving Or Impacting (e.g., pile drivers, jack hammers)
174	Electricity, Conductors And Insulators
175	Boring Or Penetrating The Earth
176	Nuclear Reactions And Systems
177	Weighing Scales
178	Telegraphy (includes television)
179	Telephony
180	Motor Vehicles
181	Acoustics
182	Fire Escapes, Ladders, Scaffolds
184	Lubrication
187	Elevators
188	Brakes
191	Electricity, Transmission To Vehicles
192	Clutches And Power-Stop Control
193	Conveyers, Chutes, Skids, Guides And Ways
194	Check-Controlled Apparatus (e.g., coin, token or card operated devices)
195	Chemistry, Fermentation
197	Typewriting Machines
198	Conveyers, Power-Driven
200	Electricity, Circuit Makers And Breakers
202	Distillation: Apparatus
203	Distillation: Processes, Separatory
204	Chemistry, Electrical And Wave Energy (processes including electrolysis, electrophoresis, electro-osmosis and liquid separation by physical-chemical action of an electrical stress)
206	Special Receptacles And Packages (e.g. glasses cases, medicine chests, key cases, milk cartons)
208	Mineral Oils: Processes And Products (e.g., crude oil refining)
209	Classifying, Separating And Assorting Solids
210	Liquid Purification Or Separation
211	Supports, Racks
212	Traversing Hoists
214	Material Or Article Handling (e.g., vehicle loading and unloading systems)
215	Bottles And Jars
217	Wooden Receptacles

Class	Title
219	Electric Heating (e.g., arc welding and cutting, electrically heated tools and instruments)
220	Metallic Receptacles
221	Article Dispensing (i.e., a discrete article; e.g., napkin dispenser)
222	Dispensing (i.e., dispensing a fluent mass material; e.g., talcum powder dispenser)
223	Apparel Apparatus
224	Package And Article Carriers (e.g., tool carriers, watch bands, trays)
225	Severing By Tearing Or Breaking
226	Advancing Material Of Indeterminate-Length (e.g., anchor line windlass, sprocketed feeders)
227	Elongated-Member-Driving Apparatus (e.g., nail, stud, staple drivers)
228	Metal Fusion-Bonding Apparatus
229	Paper Receptacles (e.g., bags, envelopes, wrappers)
233	Centrifugal-Bowl Separators
235	Registers (e.g., cash registers, computational equipment, etc.)
236	Automatic Temperature And Humidity Regulation
237	Heating Systems
238	Railways, Surface Track (e.g., road bed structure, stringers, ties, track fastening, etc.)
239	Fluid Sprinkling, Spraying And Diffusing
240	Illumination (e.g., lamps, lanterns, shades, reflectors)
241	Solid Material Comminution Or Disintegration
242	Winding And Reeling (e.g., electric coils, bobbins, spools, fishing reels)
244	Aeronautics
246	Railway Switches And Signals
248	Supports (miscellaneous specialized support and bracket devices)
249	Static Molds (e.g., concrete molds)
250	Radiant Energy (e.g., photo-cells, X-Ray systems)
251	Valves And Valve Actuation
252	Compositions (e.g., catalysts, non-resinous mixtures of two or more substances)
254	Pushing And Pulling Implements (e.g., hoist trucks, jacks, nail extractors, cable devices, etc.)
256	Fences
259	Agitating (e.g., stirrers, mortar mixers, kneaders)
260	Chemistry, Carbon Compounds
261	Gas And Liquid Contact Apparatus (e.g., for mixing gases with liquids)
264	Plastic And Non-Metallic Article Shaping Or Treating Processes
266	Metallurgical Apparatus
267	Spring Devices
269	Work Holders (e.g., clamps, vises, work tables)
270	Sheet-Material Associating Or Folding
271	Sheet Feeding Or Delivering (e.g., devices for removing individual sheets from a stack)

Class	Title
272	Amusement And Exercising Devices
273	Amusement Devices, Games (includes sports equipment)
274	Sound Recording And Reproducing
277	Joint Packing (sealing against the passage of fluids between adjacent members)
279	Chucks Or Sockets
280	Land Vehicles (generally non-motorized, e.g., carts, trailers, bicycles)
285	Pipe Joints Or Couplings
287	Rod Joints Or Couplings
290	Prime-Mover Dynamo Plants (e.g., turbogenerators; hydrogenerators; wind, tide and wave powered generators)
292	Closure Fasteners (e.g., latching devices)
294	Handling, Hand And Hoist-Line Implements (e.g., grapples)
296	Land Vehicles, Bodies And Tops
297	Chairs And Seats
298	Land Vehicles, Dumping
299	Mining Or In Situ Disintegration Of Hard Material
301	Land Vehicles, Wheels And Axles
302	Conveyers, Fluid Current (e.g., pneumatic conveyers)
303	Fluid-Pressure Brake And Analogous Systems
305	Wheel Substitutes For Land Vehicles (e.g., tracks and treads)
307	Electrical Transmission Or Interconnection Systems (includes solid state device circuits, timing circuits and electrical switching systems)
308	Machine Elements, Bearings And Guides
310	Electrical Generator Or Motor Structure
312	Supports, Cabinet Structures (e.g., record holders, radio cabinets)
313	Electric Lamp And Discharge Devices (e.g., grids, anodes, cathodes, lamp envelopes, spark plugs)
315	Electric Lamp And Discharge Devices, Systems (e.g., cathode ray tube circuits)
317	Electricity (e.g., safety and protection systems; polarity reversing, igniting, switchboard devices; circuits and relays, barrier layer devices and capacitors)
318	Electricity, Motive Power Systems (e.g., electric motors, servo systems)
320	Electricity, Battery And Condenser Charging And Discharging
321	Electricity Conversion Systems (e.g., rectification, phase and frequency conversion)
322	Electricity, Single Generator Systems
323	Electricity, Voltage Magnitude And Phase Control Systems
324	Electricity, Measuring And Testing
325	Modulated Carrier Wave Communication Systems
328	Miscellaneous Electron Space Discharge Device Systems (e.g., pulse generators)
329	Demodulators And Detectors
330	Amplifiers
331	Oscillators
332	Modulators
333	Wave Transmission Lines And Networks

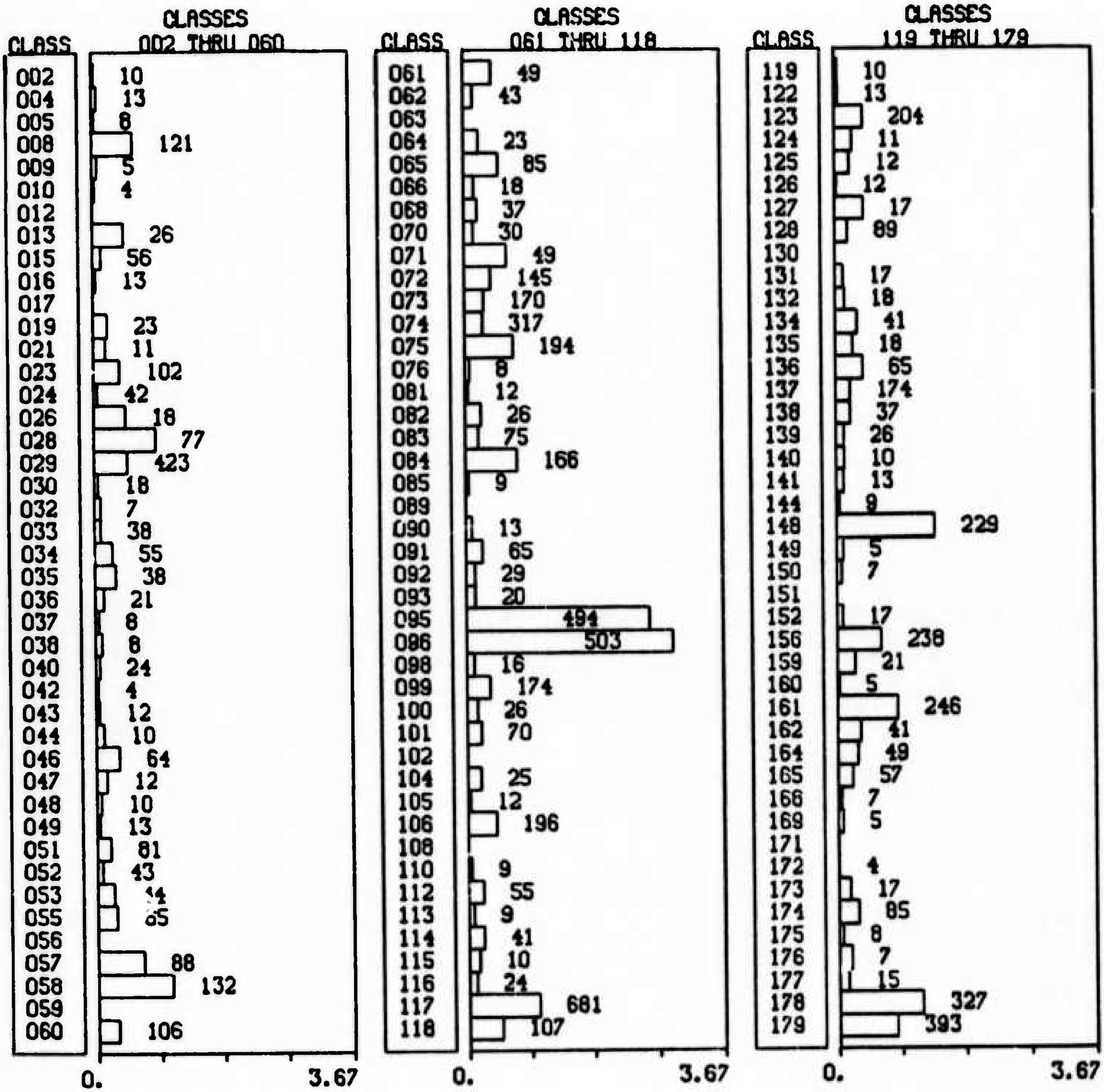
Class	Title
334	Tuners
335	Electricity, Magnetically Operated Switches, Magnets And Electromagnets
336	Inductor Devices
337	Electricity, Electrothermally Or Thermally Actuated Switches
338	Electrical Resistors
339	Electrical Connectors
340	Communications, Electrical (e.g., data processing, traffic control, telemetry systems)
343	Communications, Radio Wave
346	Recorders (includes apparatus for recording the movement of machines and various phenomena; e.g., workmen's time-clock, seismic cameras)
350	Optics, Systems And Elements
351	Optics, Eye Examining, Vision Testing And Correcting
352	Optics, Motion Pictures
353	Optics, Image Projectors
355	Photocopying
356	Optics, Measuring And Testing (e.g., range finders, photometers, spectroscopes, etc.)
401	Coating Implements With Material Supply (e.g., ball point pens, paint rollers with reservoir, pencils, lipsticks, etc.)
408	Cutting By Use Of Rotating Axially Moving Tool (e.g., drill presses)
415	Rotary Kinetic Fluid Motors Or Pumps (includes water wheels, turbines and blowers)
416	Fluid Reaction Surfaces (i.e., impellers)
417	Pumps (e.g., complete pumps with drive and pump systems)
418	Rotary Expansible Chamber Devices (rotary expansible chamber pump and motor, including internal combustion motor)
423	Chemistry, Inorganic
424	Drug, Bio-Affecting And Body Treating Compositions
425	Plastic Article Or Earthenware Shaping Or Treating: Apparatus
431	Combustion (e.g., incandescent mantle, cigarette lighters; burners with features specialized to combustion)
432	Heating (includes processes of heating an article, industrial furnaces)

Classes Excluded from Country and State Profiles

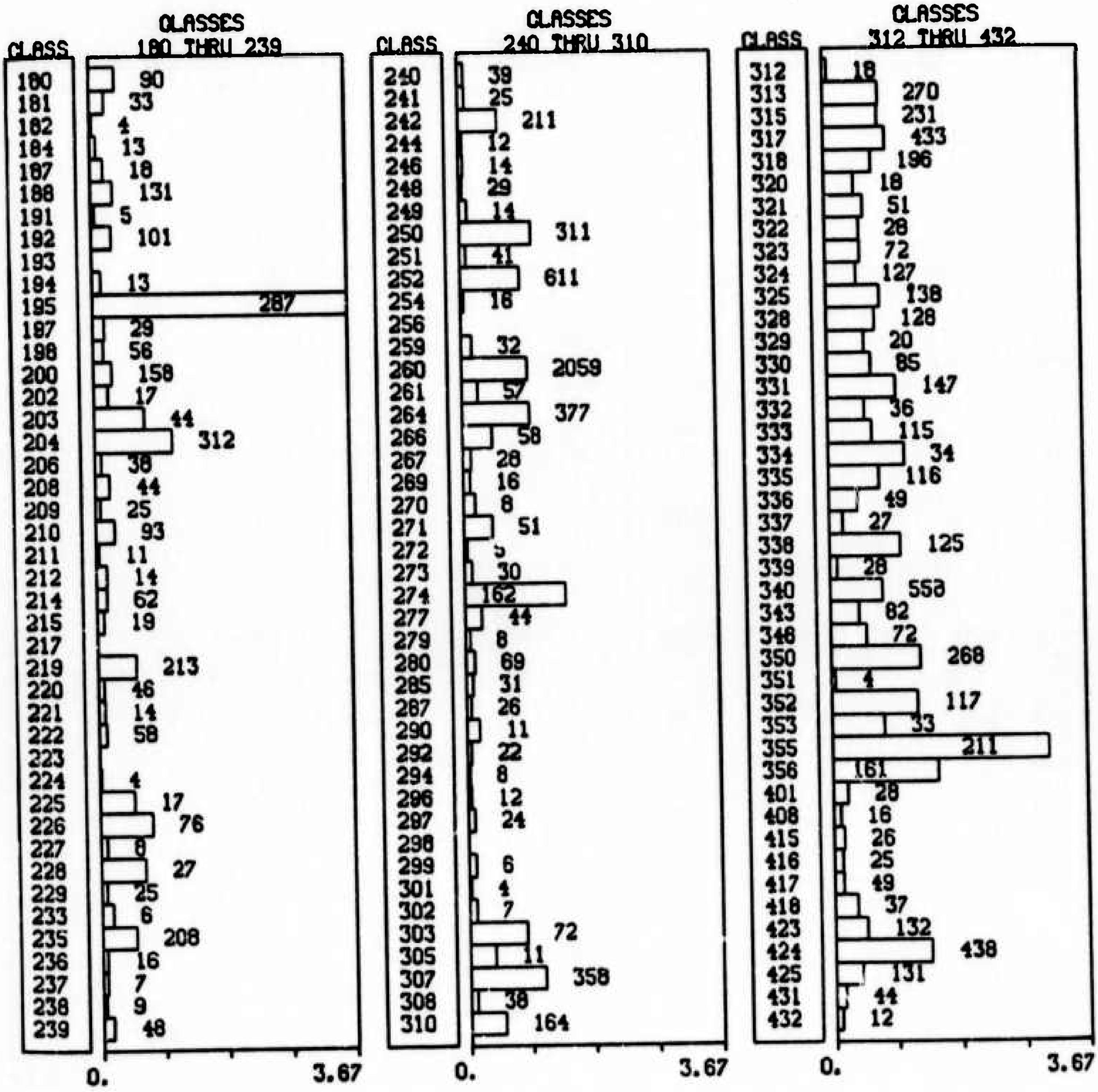
The following classes were not treated in the country and state profiles because of their very small size or their lack of significant current activity for any country.

Class	Title
3	Artificial Body Members
6	Bee Culture
7	Compound Tools
11	Books, Making
14	Bridges
27	Undertaking
54	Harness

TECHNOLOGICAL ACTIVITY PROFILE: JAPAN

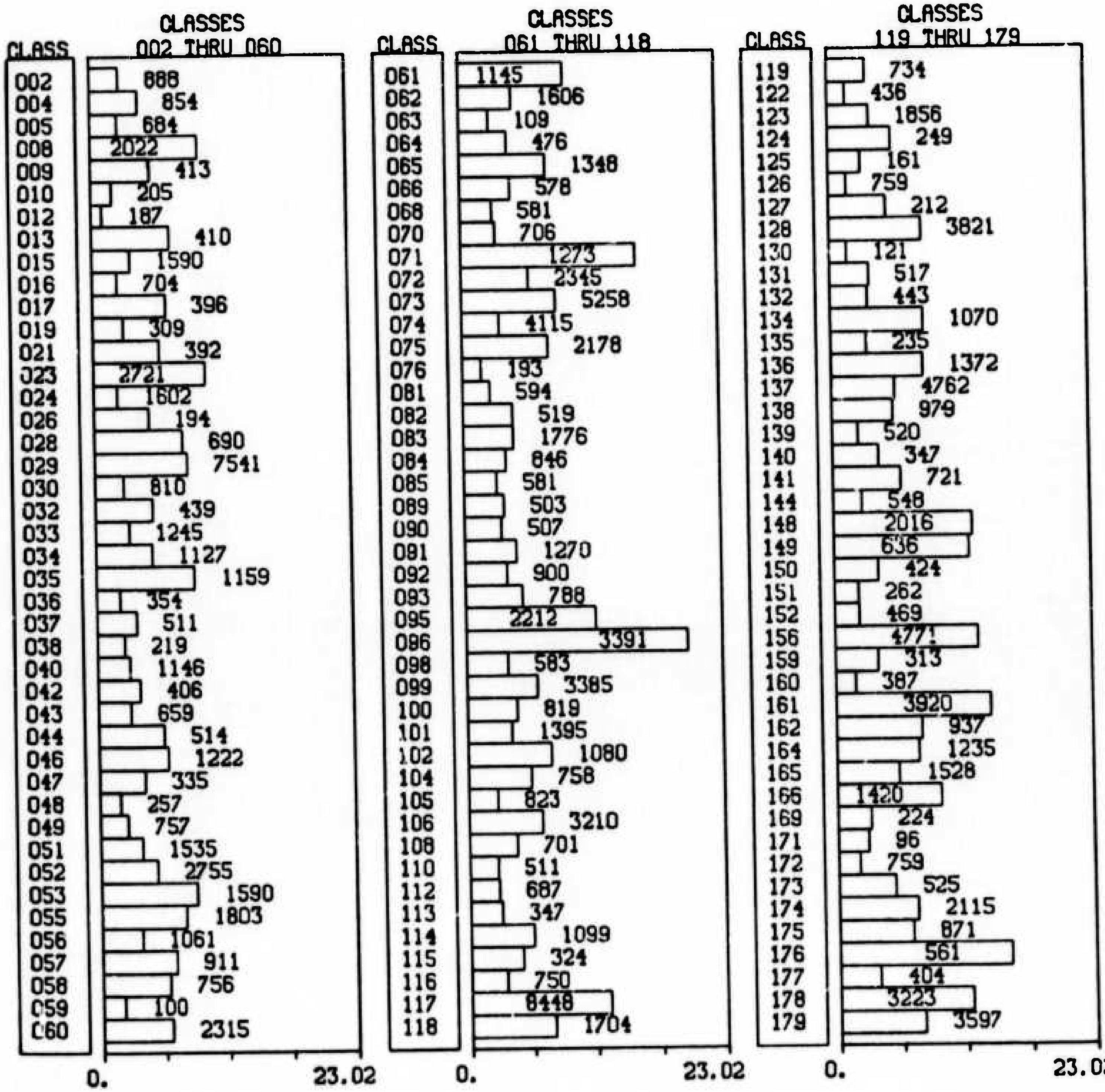


Bar length represents the ratio of patents issued to residents of Japan during the three years ending 6/30/73 to each hundred total patents in the class. Number within or beside the bar represents the number of patents in the class issued to residents of Japan during that three year period.

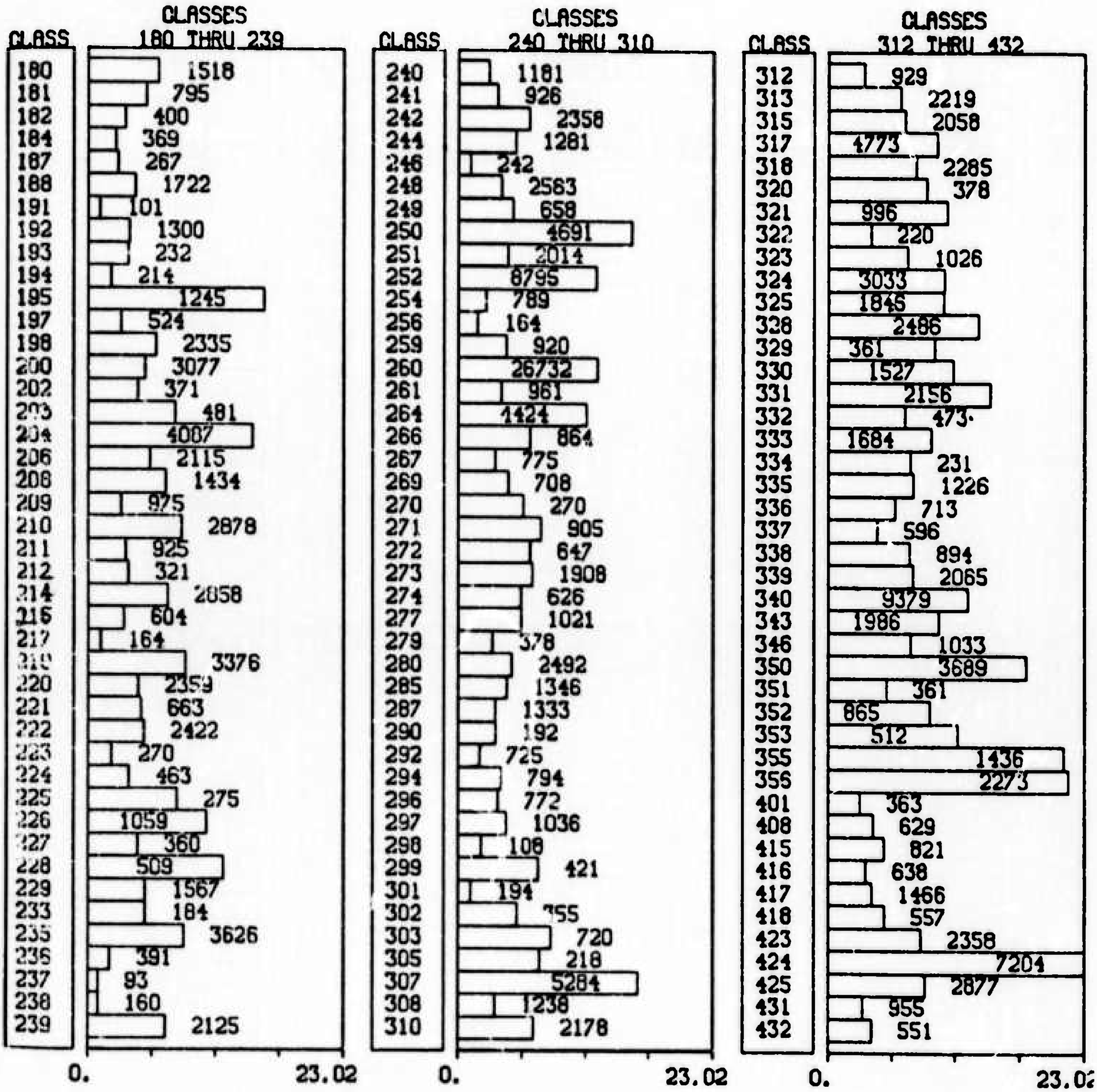


Titles corresponding to the class numbers appear in Appendix 1

PROFILE OF OVERALL TECHNOLOGICAL ACTIVITY



Bar length represents the ratio of all patents issued during the three years ending 6/30/73 to each hundred total patents in the class. Number within or beside the bar represents the number of all patents issued during that three year period.



Titles corresponding to the class numbers appear in Appendix 1